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Microstraining and Disinfection of Combined Sewer Overflows

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MICROSTRAINING AND DISINFECTION OF COMBINED SEWER OVERFLOWS

by

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for the

FEDERAL WATER QUALITY ADMINISTRATION

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ABSTRACT

Microstraining(C), using a Microstrainer screen of a nominal aperture size of 23 microns, removes up to 98% of the suspended solids from a combined sewer overflow. The sewer, which has an average sanitary sewage flow of 1,000 gph, serves a residential area of 11 acres in the City of Philadelphia. The maximum combined sewer flow recorded during rainstorms in one year of operation has been 11.3 cfs (304,000 gph).

Volatile suspended solids removals with the 23-micron Microstrainer screen have averaged 68% and 71% during different test periods.

BOD removals and coliform bacteria concentrations in the Microstrained effluents have varied widely. Postulations as to the effects of Microstraining on both actual concentrations and on the measurement techniques are given.

Results to date indicate that there is a slightly better kill of coliform group bacteria with chlorine than with ozone in the Microstrainer effluents when both are used at an initial nominal concentration of 5 ppm, with 5 to 12 minutes detention time. However, chlorine has been applied at slightly higher levels and with better control than the ozone, and it has not been possible to optimize requirements for these chemical feeds. Limited tests indicate that higher dosages of chlorine for shorter contact times may be the most efficient and economical approach.

Preliminary estimates of the costs of treatment for a combined sewer via the Microstraining process, using tentatively-established Microstrainer throughput rates, show that the capital costs per acre of drainage for a full-scale plant in a similar area would be approximately $10,200 for Microstraining alone, $11,200 for Microstraining plus chlorination, and $19,800 for Microstraining plus ozonation. The first two cost figures compare favorably with other techniques that have been proposed. For example: the costs associated with construction of separate storm and sanitary sewers have, in several cases, been estimated to range between $20,000 and $23,000 per acre. Of eight other currently-proposed schemes, whose costs we have roughly estimated, only surface impoundment (where aesthetically acceptable and where low-cost land is available) appears competitive.

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More reliable cost estimates for Microstraining could be derived through additional investigation at the higher throughput rates. Such investigation was begun during the latter part of the program. We have also performed preliminary calculations which show that installations ten or more times as large may produce per acre costs 20% to 30% lower than these estimates.

Moreover, if the market for Microstrainers were to increase substantially, it is probable that lower production costs would result in savings to users.

This work has been conducted with the cooperation of the City of Philadelphia in fulfillment of Contract No. 14-12-136 between the Federal Water Quality Administration and the Cochrane Division of Crane Co.

Key Words: Microstraining, combined sewer overflows, solids removal, ozonation, chlorination, BOD removal, treatment costs.

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SECTION I

RESULTS AND CONCLUSIONS

The preliminary information developed in this work indicates that treatment of combined sewer overflows via Microstraining can furnish a high degree of solids removal at a per-acre cost of approximately 40% to 50% of the cost of sewer separation in cities where separation has been considered[1], such as Washington, D.C., Philadelphia and Chicago. Treatment of an actual overflow in a residential area of Philadelphia has produced solids removals of up to 98%. Limited data for a fine Mark "0" (23 micron) screen, under relatively high throughput conditions, show removal figures ranging from 78% to 98%, with an average of 91%. Figures for a larger number of tests made with lower throughputs show a solids removal range of 62% to 96%, with an average of 80%.

Volatile suspended solids removals have roughly paralleled the experience with total suspended solids. These removals for the Mark "I" (35 micron) screen averaged 47% and, for three modes of operation using the Mark "0" screen, have averaged 68%, 71% and 71%.

Bacteriological measurement changes across the Microstrainer screens exhibit anomalies, with both reductions and increases in total and fecal coliform counts. Further large reductions in total coliform count can, of course, be achieved with chlorine or ozone. Our results, with both ozone and chlorine, although again anomalous in some instances, indicate a slightly better performance with chlorine at the concentrations used. However, chlorine has been used at a 5 ppm feed rate, the chlorine detention times usually being 5 and 10 minutes; while the ozone, whose detention period was about 12 minutes, was used at 3.8 ppm. Average values for total residual coliform after treatment were 166,000, 129,000 and 619,000 per 100 ml respectively. These values for fecal coliform were 41,000, 81,000 and 42,000. We attribute the seemingly better performance of the chlorine to a more positive mode of chlorine addition and a higher feed rate than has been possible with the ozone. In some work, carried out near the end of the program, 15 ppm of chlorine with only 2 minutes detention produced greater bacterial kills than the lower concentration with longer detention.

Several possible explanations for the apparent increases across the Microstrainer have been postulated:

1. Natural predators for bacteria are largely removed by Microstraining and are thus not present in large numbers on the discharge side.

2. Large clumps of bacteria are broken up into numerous smaller clumps or singlets by passage through the screen.

3. The bacterial food supply is made more available (more surface area is produced on the escaping solids) by the screening process, and growth kinetics are enhanced. This is perhaps reflected in some of the BOD_5 measurements in which increases were observed across the Microstrainer.

   BOD removals across the Microstrainer have been difficult to measure. In those cases where reductions have been recorded across the Mark "0" screen, the average reduction has been 65%. However, in 8 of 17 measurements made while this screen was in service, increases in BOD were shown.

Analytical results from the City of Philadelphia Water Department's Research and Development Group[2] indicate that, in one set of samples taken at the end of the program, predators were absent from the Microstrainer effluent, while present in the influent, and this may be a factor. However, the third explanation may also be important, and we believe that such effects of the Microstraining process can be desirable in the treatment of stormwater:

1. Smaller particles will have less tendency to occlude bacteria. They are thus more vulnerable to attack from ozone or chlorine.

2. If the BOD is exerted over a shorter time period, downstream effects will be less persistent.

The special characteristics of stormwater overflow are vastly different from characteristics of other municipal waste waters, and they will require a different treatment approach. Foremost among these special characteristics are perhaps the high instantaneous flow rates and the fact that the treatment facility must operate for only relatively short time periods, usually following relatively long idle periods.

Two very different treatment schemes show the lowest costs. A small, full-flow, unattended plant consisting of a Microstrainer operating at a high rate, together with a chlorination chamber of low detention time, can satisfy the space, flow rate, and quality limitations in the majority of instances, at capital and operating costs significantly lower than

most other proposed schemes. A surface impounding basin located at an existing outfall, with low-rate repumping to a sewage plant, has been reported practical in one case[3], and it should be in other locations where low-cost land is available at the outfall and impoundment is aesthetically permissible.

"Pretreatment" of the Microstrainer influent by means of a heavy-solids trap and a bar screen are recommended for full-scale installations.

Estimates for installed capital costs for various types of installations based on a drainage area similar to the one used in this work are:

1.	Bar screening and Microstraining	$10,200 per acre
2.	Bar screening, Microstraining and chlorination @ 5-20 ppm	$11,200 per acre
3.	Bar screening, Microstraining and ozonation @ 5 ppm	$19,800 per acre

SECTION II

RECOMMENDATIONS

1. In order to bring more realism to studies of this type, regulatory agencies should define acceptable effluent qualities for several typical combined sewer overflow situations.

2. The performance of a Microstrainer at the high flow rates reported herein should be confirmed by additional work, and extended to determine the maximum and the optimum flow rates for solids removal, should they exist. This investigation should also provide information on the effects of Microstraining on bacterial concentrations and growth characteristics, and develop routine measurement techniques that meaningfully reflect these changes.

3. The low-residence, high-chlorine-dose bacterial kill should be confirmed by additional work.

4. The ozonation work should be continued, to optimize ozone use in this application.

5. Where ozone is chosen for disinfection of the Microstrainer effluent in a full-scale plant, oxygen should be used on a once-through basis in place of air.

6. A full-scale, in-line Microstrainer and chlorination facility, without an impounding basin, should be built as a demonstration plant.

SECTION III

INTRODUCTION

The pollution problems associated with combined sewer overflows in our cities have multiplied and grown enormously over the past 20 to 30 years. The increased concentration and growth of urban activities have brought this about, and these problems have been subjected to much technical and economic study. The studies have been intensified and broadened, particularly over the past 15 years or so, because of increased public awareness of the severity of the overall problem of pollution of our streams and coastal waters.

Exact figures are difficult to obtain--and they are certainly variable over a wide range in relation to such factors as sewer design and service, time of day, intensity and frequency of rainfall and character of the drainage area--but the contribution to pollution of the combined overflows is of considerable magnitude. An example is data reported from Buffalo, N.Y.[1], which indicated that one-third of the city's annual production of sewage solids overflowed without treatment, although only 2% to 3% of the sewage volume actually overflowed. And, in a special three-year study conducted at Northampton in England[4], it was estimated that the overflow loads of suspended solids, COD, and BOD discharged in a year of average rainfall would be respectively 132, 62, and 35 times the daily dry-weather load, with an overflow setting of three times the dry-weather flow. Further, work accomplished at Detroit, Mich.[5] is reported to show that bacterial contamination effects in the receiving stream persist for several days after discharge has ceased, and the duration of effects increases with an increase in storm intensity.

Heavy debris and sludge deposits in receiving streams below sewer outfalls are common, and are considered to be long-term contributors to pollution, because only their surface layers are readily accessible to natural purification processes.

Among the possible solutions to the problem that have been proposed, and in some cases implemented, are separate and parallel storm and sanitary systems, separate sanitary systems piped within larger storm sewers, retention tanks for combined sewer overflows, in-system storage for peak flows, control of runoff by modifying the surface of the drainage area, various treatment processes, and combinations of these.

The costs of sewer separation for the entire country have been variously estimated at 25 to 30 billion dollars[1] and higher[6], depending on the factors considered in arriving at the estimates. And many municipalities indicate that the practical possibility of changing all combined sewers to separate is remote[7].

In a more recent estimation, it is suggested that street refuse can present a significant pollution load[8]. There is thus a growing body of opinion that the quality of separated urban stormwater is such that this separated stormwater should be treated in some manner prior to discharge into natural waters.

It now seems obvious that, for a variety of reasons, the concept of separate storm and sanitary systems is not, at least by itself, the answer to the problem. Rather, conclusions from information gathered in an extensive survey[7] point out that different solutions and combinations of solutions will be required in different localities, depending upon local circumstances. These circumstances include not only the discharge systems, rainfall, areal characteristics, etc., but also the desired character of the effluents as they relate to the receiving stream or body of water.

This work has consisted of the design, installation, operation, and evaluation of Microstraining equipment, and of ozonation and chlorination at a typical combined sewer overflow. Operation has not been extensive enough to permit complete evaluations; however, information available permits preliminary conclusions regarding Microstrainer operation on this type of combined sewer overflow.

Initially, the Microstrainer was fitted with a Mark "I" screen. Results indicating effluents of intermediate quality were obtained from nine suitable rainfalls occurring within a 6-month period.

A finer, Mark "0", screen was then fitted to the Microstrainer. Effluent qualities, with respect to removals of total and volatile suspended solids, increased measurably.

After an additional eight usable rainfalls, the Microstrainer controls were altered to produce a pre-established constant differential head across the Microstrainer screen. Results from six sets of samples during three different rainfalls indicated still further improvement in suspended solids removals.

Finally, the differential head was increased well above the normal level noted above, by blanking off much of the screen area. This reduction in screen area amounts to about 80%, and has resulted in high suspended solids removals. These results are most significant because they suggest that much higher hydraulic loadings, with attendant lower capital costs, give better results.

These last tests, although few in number, indicate that the Microstrainer Mark "0" screen in this service is superior to the Mark "I" coarser screen, and that the Mark "0" performs well at a higher hydraulic loading. No evidence of screen plugging has been observed at any time.

The work reported here should provide a basis for the use of additional tools for combatting a complex pollution problem.

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SECTION IV

EXPERIMENTAL EQUIPMENT AND TEST SITE

Microstrainer

The test system uses Microstraining for the removal of suspended solids and associated impurities, followed by ozonation or chlorination for disinfection. The Microstrainer is a drum filter 5 feet in diameter by 3 feet long, with a specially woven wire fabric of stainless steel as the filter medium. In this work, two different types of screen have been employed; the Mark "I" (nominal aperture 35 microns), and the Mark "0" (23 microns). In operation, the drum is submerged in the flowing water to approximately two-thirds of its depth. Raw water enters through the upstream end of the drum and flows radially outwards through the microfabric, leaving suspended solids deposited on the inside of the mesh. The drum rotates continuously, at variable speeds, carrying the dirty fabric out of the water and under backwashing jets mounted across the top of the drum.

In general, drum rotation should be as slow as possible, consistent with throughput and an acceptable differential head across the microfabric. This is because of the filtering advantage usually provided by the initial buildup of a layer of solids on the microfabric. The controlled variability of drum rotational speed thus becomes a key feature of the Microstraining process, and the speed is controlled by the differential head best suited to the circumstances involved.

Intercepted solids are flushed into a receiving trough fitted inside the drum with its top edge above the water level. In a full-scale project, these solids would be returned to the interceptor sewer for disposal to the nearest sewage treatment plant.

Inasmuch as ultraviolet radiation can inhibit the formation of bacterial and other organic slimes, which tend to foul the Microstrainer fabric, the Crane-Glenfield Microstrainer is equipped with an ultraviolet irradiation source. This source is positioned over the revolving drum parallel to the backwash jet headers, and it is designed to avoid the production of ozone. Ozone, produced from oxygen in air, can be deleterious to the microfabric.

Microstrainers of this type have been employed since 1945 for the filtration of municipal and industrial water supplies, and more recently for "tertiary" treatment of sewage effluents[9].

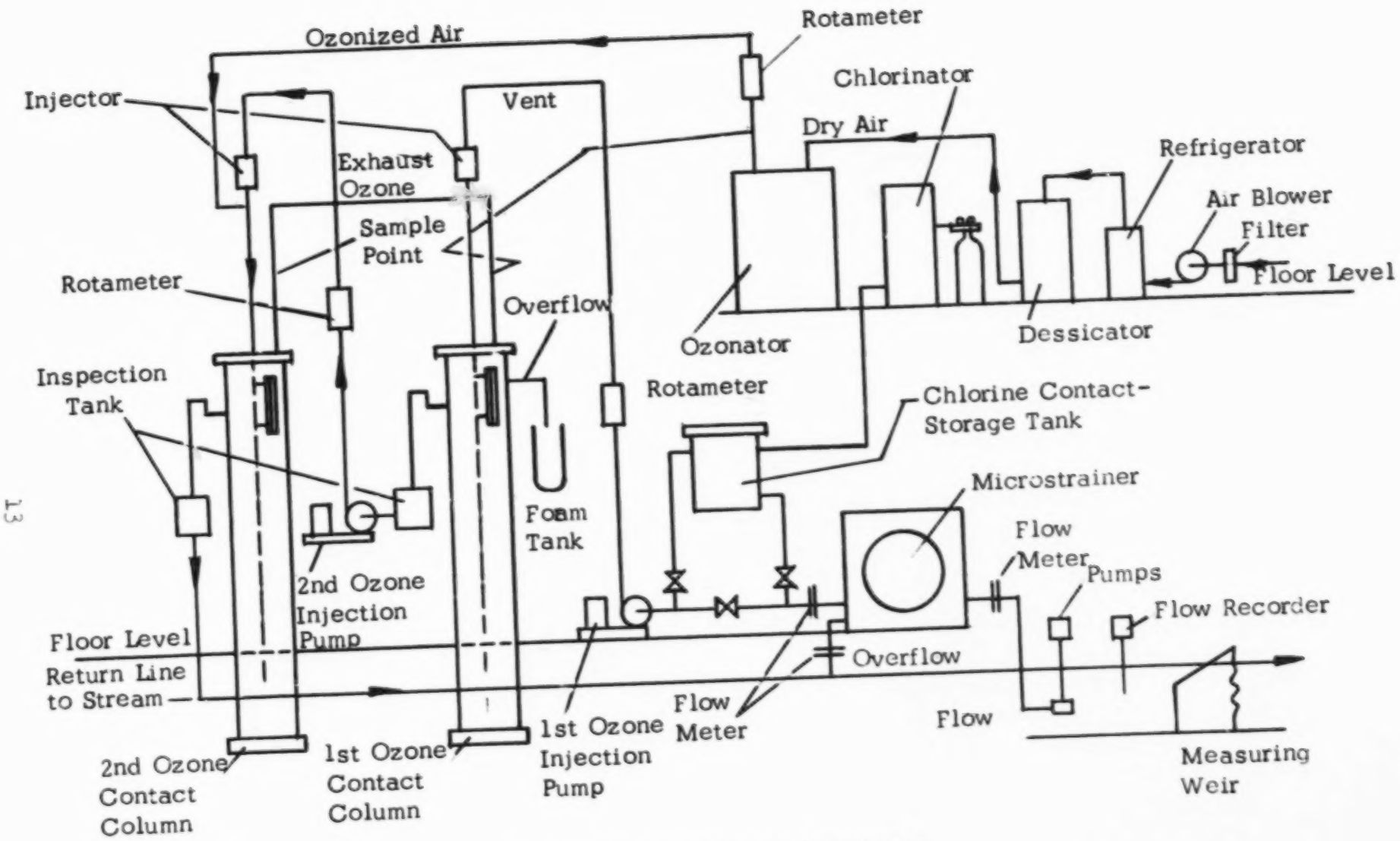
Chemical Equipment

After water passes through the Microstrainer, it is collected in a 1,200-gallon storage tank, for ozonation or chlorination. Ozone is generated in an Otto* Plate Type (Model 3-63) Ozonizer. This ozone generator has 15 plate-type elements, and is rated at 300 grams of ozone per hour, at a concentration of 20 grams per cubic meter of air, for a maximum power load of 7 kw. Energy to the high-voltage electrodes is variable from 7,000 to 15,000 volts. The maximum cooling water needed is 11 gallons per minute at 15-foot head. Air drying equipment consists of a refrigerator and desiccator. Electrical control panels are also provided. The air is supplied by a 1/2 hp blower and is filtered. It is cooled to 2 to 5° C, and desiccated in silica-gel columns to a dew point of -40° C. The concentration of ozone in air, and the amount of ozone introduced into the water, can be varied by adjusting the air flow and the voltage to the ozone generator.

In the CEO Otto system that is used (Figures 1 and 2), ozonized air is mixed with the water in injectors powered by pumps. Two pump injector sets are used, each set supplying one of two contact columns connected in series. The water and ozonized air mixtures travel down through centrally-located pipes in the columns, and then pass upward through the columns. The water overflows at a point about 12 inches from the tops of the columns, and the air, with some residual ozone exhausts at the tops of the columns. The overall gas-liquid flow is counter current, with the water in the first column being initially contacted with ozone exhausted from the second column. The water from the first column is then pumped to the second, where it is contacted with full strength ozonized air. The treated water is discharged through a sampling tank to the surface stream.

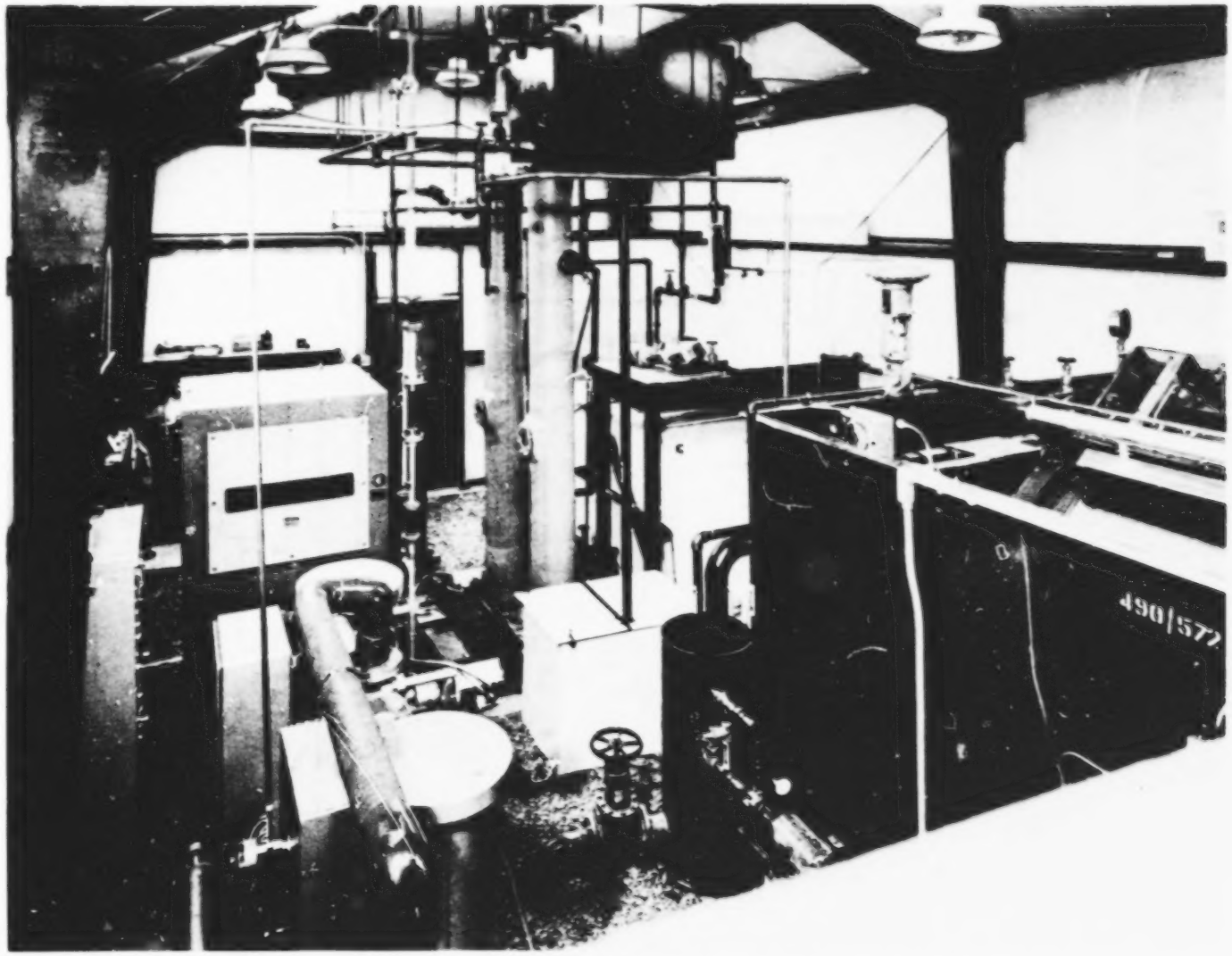
The columns are 17 feet high by 12 inches in diameter with the central downpipes 1-1/2 inches in diameter.

*Supplied by La Compagnie des Eaux et de l'Ozone (CEO) of Paris, France.



Equipment Installation-Schematic

Figure 1



Treatment Equipment, Air Preparation and Ozone Generator-Left, Ozone Contact Columns-Center, Microstrainer-Right
Figure 2

This system can be described as a combination co-current and counter current contactor, since within the columns the gas and water flow in the same direction, but the sequence of passage of liquid through successive absorbers is counter current to the gas sequence.

In an actual plant, where operation is intermittent, it would seem desirable from a capital cost standpoint to use an oxygen, rather than an air, supply to the ozonizer. Using oxygen, the concentration of ozone generated is twice that with air. Thus the ozone generator size can be halved.

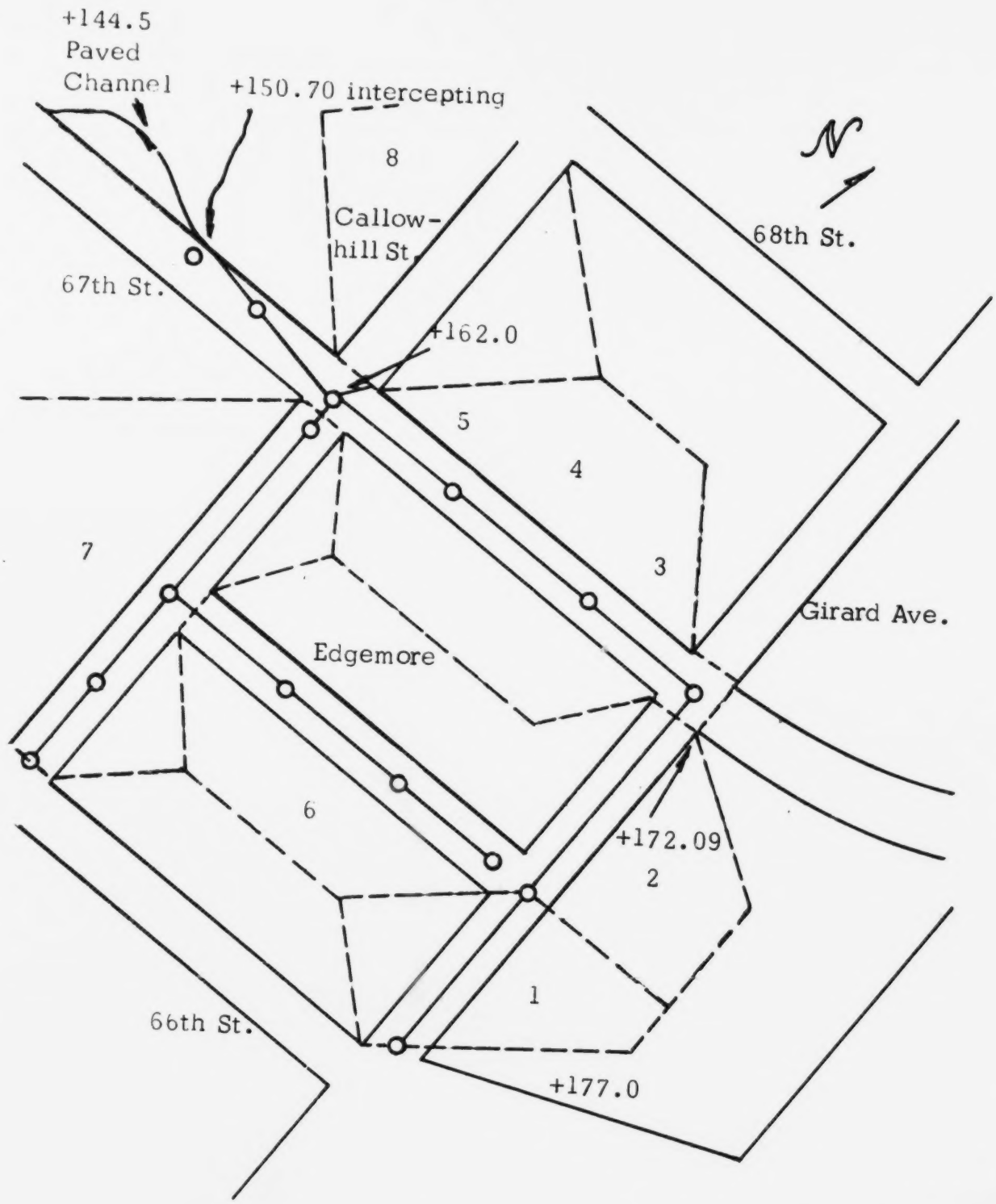
We suggest that oxygen would be used on a once-through basis, with no oxygen recycle, thus also eliminating the need for desiccation equipment.

Chlorination equipment supplied for the plant was a small gas chlorinator*. Originally, water was treated by means of this system, and attempts were made to retain the chlorinated effluent for varying periods of time. However, the short duration of very many of the usable rainstorms created metering and regulation problems. This, coupled with the need for a supply of water for relatively long periods of time for operation of the ozonator, forced a change in the method of chlorine treatment. Manual addition of a solution of sodium hypochlorite to samples of Microstrainer effluent from the holding tank was adopted. Close control of chlorine addition was then possible, and the residual chlorine, after chosen retention times, was destroyed by the addition of thiosulfate prior to refrigerated storage while awaiting analysis.

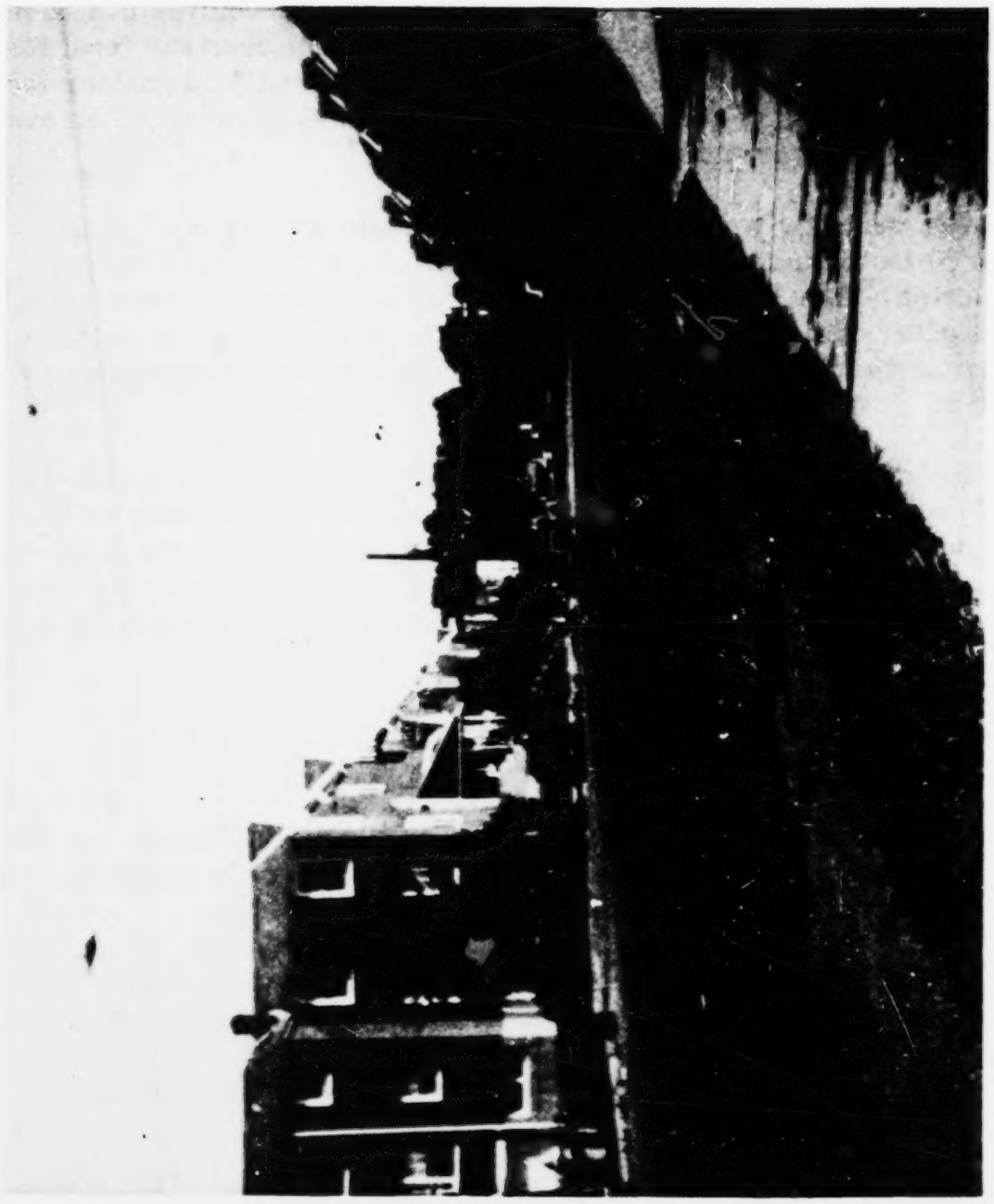
Test Site

The test site is located on the western side of Philadelphia on a sewer outfall which enters a tributary stream of Cobbs Creek, flowing eventually into the Delaware River. The outfall serves an area of approximately 11.2 acres, principally dwelling houses with paved roads and sidewalks (Figures 3 and 4). Dry-weather flow in the sewer averages 1,000 gallons per hour, and at the setting employed during the tests, the interceptor will collect up to three times this flow. In Figure 3, the dotted lines define sub-drainage areas, and the solid lines connecting the small circles (manholes) are the sewer lines. The outfall, which is 24 inches in diameter with a theoretical capacity of about 37 cfs, is located at

*Wallace and Tiernan



Outfall
67th & Callowhill
Figure 3



Drainage Area
Figure 4

elevation 148, about 3 feet below the 150.7 foot intercepting elevation.

Overflows normally take place when storms in the area exceed a rate of 0.1 inch per hour, which occurs approximately 40 times a year, mostly during the spring and summer. Hcwever, our plant requires 0.2 to 0.3 inch per hour for about 1 hour to produce sufficient overflow for a test run. The rate of overflow can reach as much as 1 million gallons per hour during a storm of 6 inches per hour, which is attained on an average of once every 5 years.

The sewer overflow was modified to incorporate a collection sump (Figure 5) from which the storm water runoff is pumped into the test installation. Rate of overflow is measured by means of a weir at the sump outlet, and is continuously recorded. A baffle wall in front of the weir prevents surges of water from upsetting the measurement of flow rate.

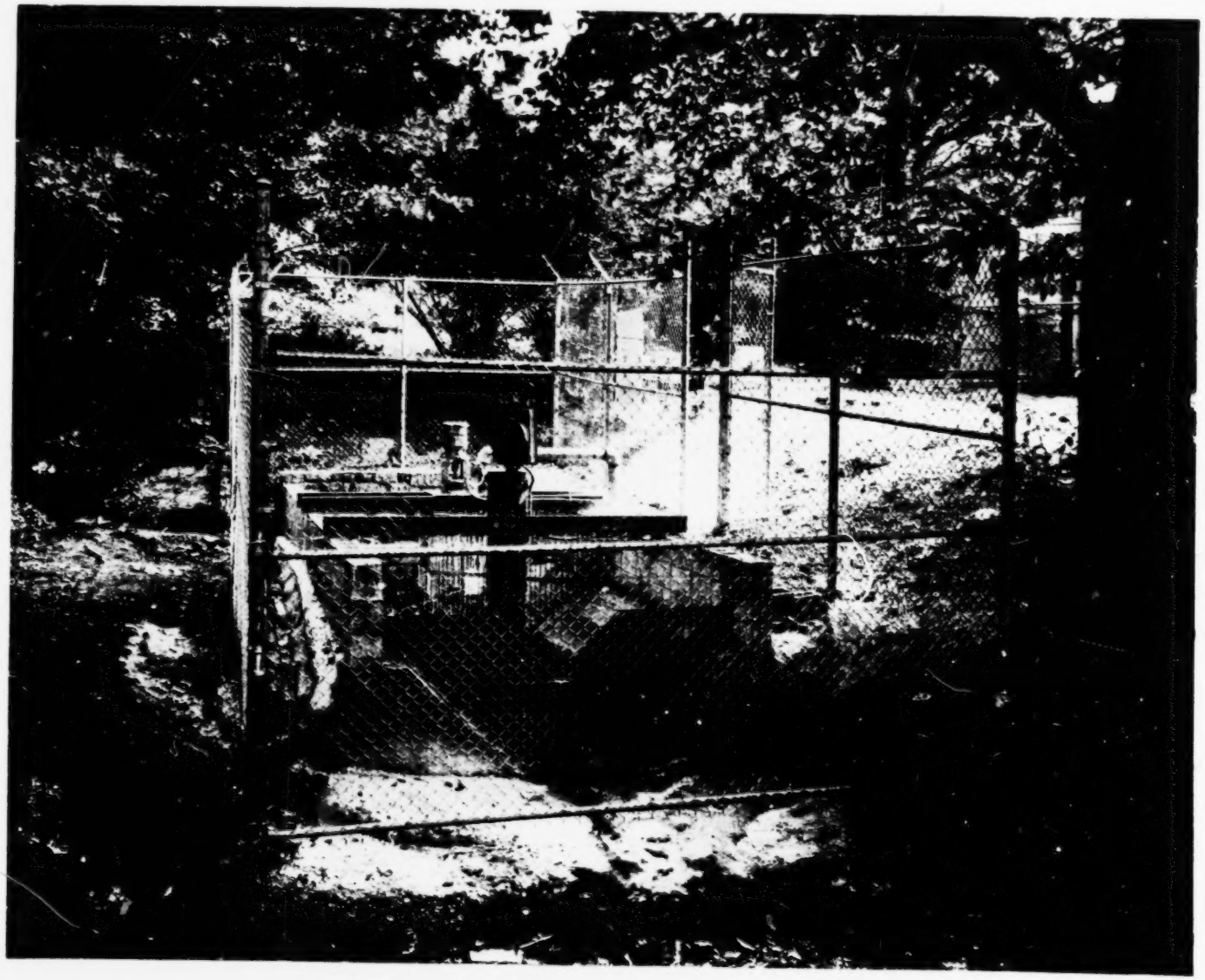
Two Microstrainer supply pumps are installed between the baffle wall and the measuring weir, one having a maximum flow capacity of 13,000 gph, and the other 5,000 gph. These pumps have been used both together and separately, to supply water at rates of 5,000 and 18,000 gph, with some intermediate and lower rates, depending on the supply heads available. Intakes to the pumps are protected by a screen with 1/2 inch square openings.

Operation

As water enters the collection sump, the level rises, starting the float-actuated pump(s) and initiating a timer connected to the sampling devices inside the test installation.

The rate of flow to the Microstrainer is recorded continuously. The pumped flow from the sump, together with the measured and recorded weir overflow, yield a measure of the total storm overflow. (The interceptor continues to carry an additional three times mean dry-weather flow.)

As water enters the Microstrainer drum, head loss through the fabric increases, and by means of a differential pressure transmitter and servo system, the drum speed is increased. The effluent flow rate from the Microstrainer is measured and recorded. Water for backwashing is drawn from the downstream side of the strainer by means of a small



Collection Sump From Overflow End
Treatment Building in Right Background
Figure 5

pump (40 psig discharge), kept supplied during dry periods from a storage tank containing city water. The Microstrainer thus commences its filtering action at the beginning of a storm, passing strained water into the collection tank. Water may be stored here for further tests or bypassed and returned to the stream.

Sampling

Composite samples of the raw and strained water are extracted automatically by two N-Con Surveyor Model Samplers and stored in refrigerated containers, from which they are collected and tested by the Philadelphia Water Department. The raw, or influent, sample is taken from the Microstrainer inlet chamber, and the effluent sample is withdrawn from a point in close proximity to the discharge side of the screen. A time delay mechanism delays the beginning of the sampling operation for 8 minutes after the supply pumps are actuated, in order to permit the accumulation of enough water in the inlet and outlet chambers of the Microstrainer for the samplers to operate. The samplers were adjusted to withdraw portions of the flows at a fixed rate every 6 minutes. The time lag between influent and effluent sample withdrawals is approximately 5 seconds. Ozonation and chlorination are carried out as soon as possible, and further samples are taken before and after this chemical treatment.

The Philadelphia Water Department performs the laboratory analysis of samples, maintains the recording rain gauge and cleans the outfall sewer after each overflow.

Submerged Screen Area

The fraction of the drum submerged was calculated from the water level inside the drum. For unattended tests, the level inside the drum was calculated from the differential pressure record.

The area of screen on the drum, when none is blanked off, is 47 square feet. In the beginning of the project the maximum drum submergence observed was 74%, or 35 square feet of microfabric. On 7/23/69, the outlet weir was lowered so that any differential would yield a lower level inside the drum and, therefore, reduce submergence. The area of the screen was later reduced to approximately 9.4 square feet. At the resulting higher differential, the submergence obtained was 78%, or 7.4 square feet of submerged microfabric.

SECTION V

RAINFALL AND RUNOFF

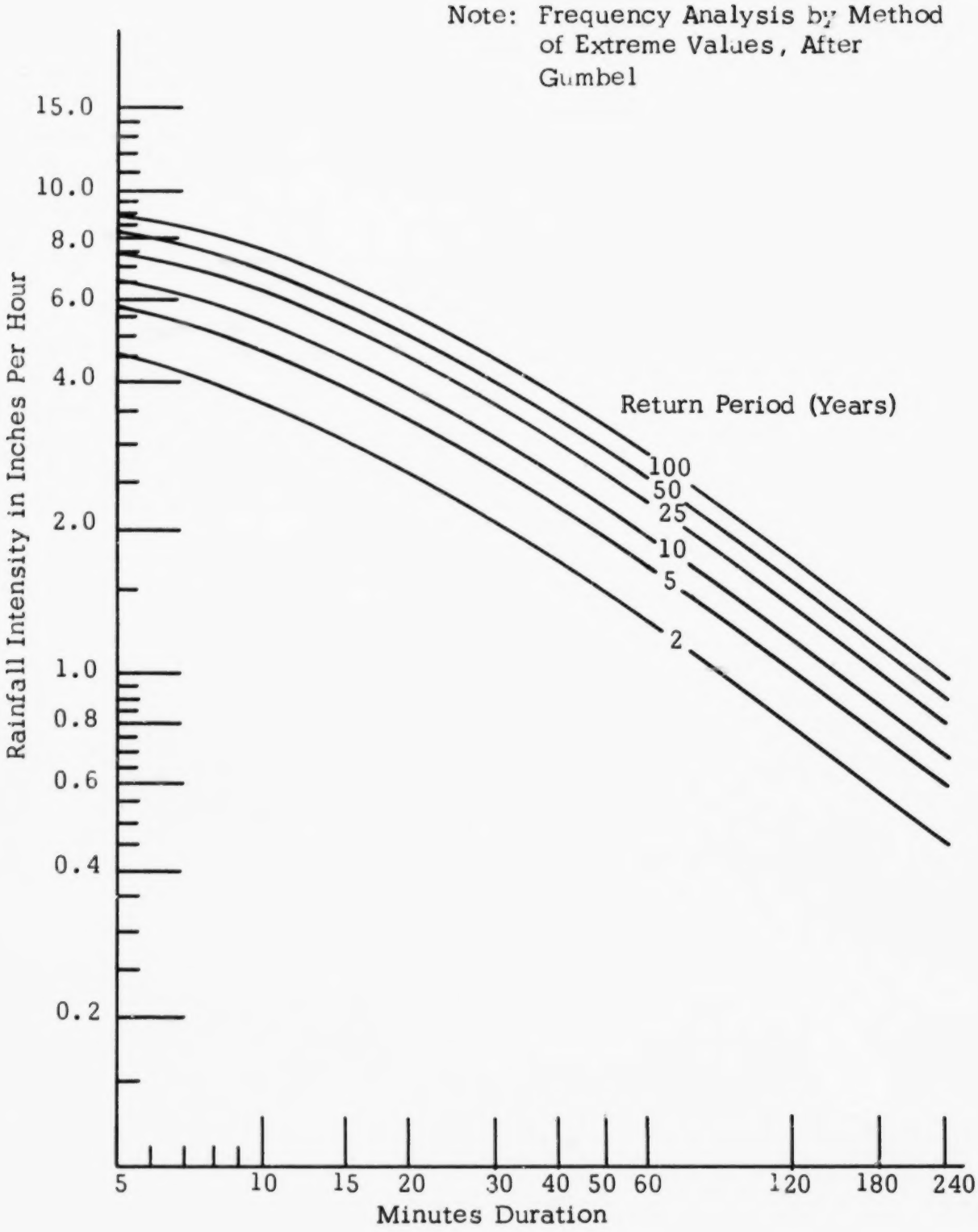
Rainfall Intensity-Return Frequency curves for the City of Philadelphia, as furnished by the City Water Department, are shown in Figure 6.

Figure 7 shows the rainfall intensities and durations that we have measured at a rain gauge* located in our test drainage area, about 100 yards from the test site, along with calculated corresponding runoff coefficients. Total flows are measured by a weir mounted at the discharge of the combined sewer trough, plus the metered quantities that are pumped to the Microstrainer. The normal sanitary flow (Figure 8) expected during the same period is subtracted and the pre-calibrated portion that flows into the interceptor through a "drop" weir preceding the outfall is added. In relation to the higher total flows, this constitutes a minor correction, since the drop weir is set to accept only three times the average dry-weather flow (1,000 gallons per hour).

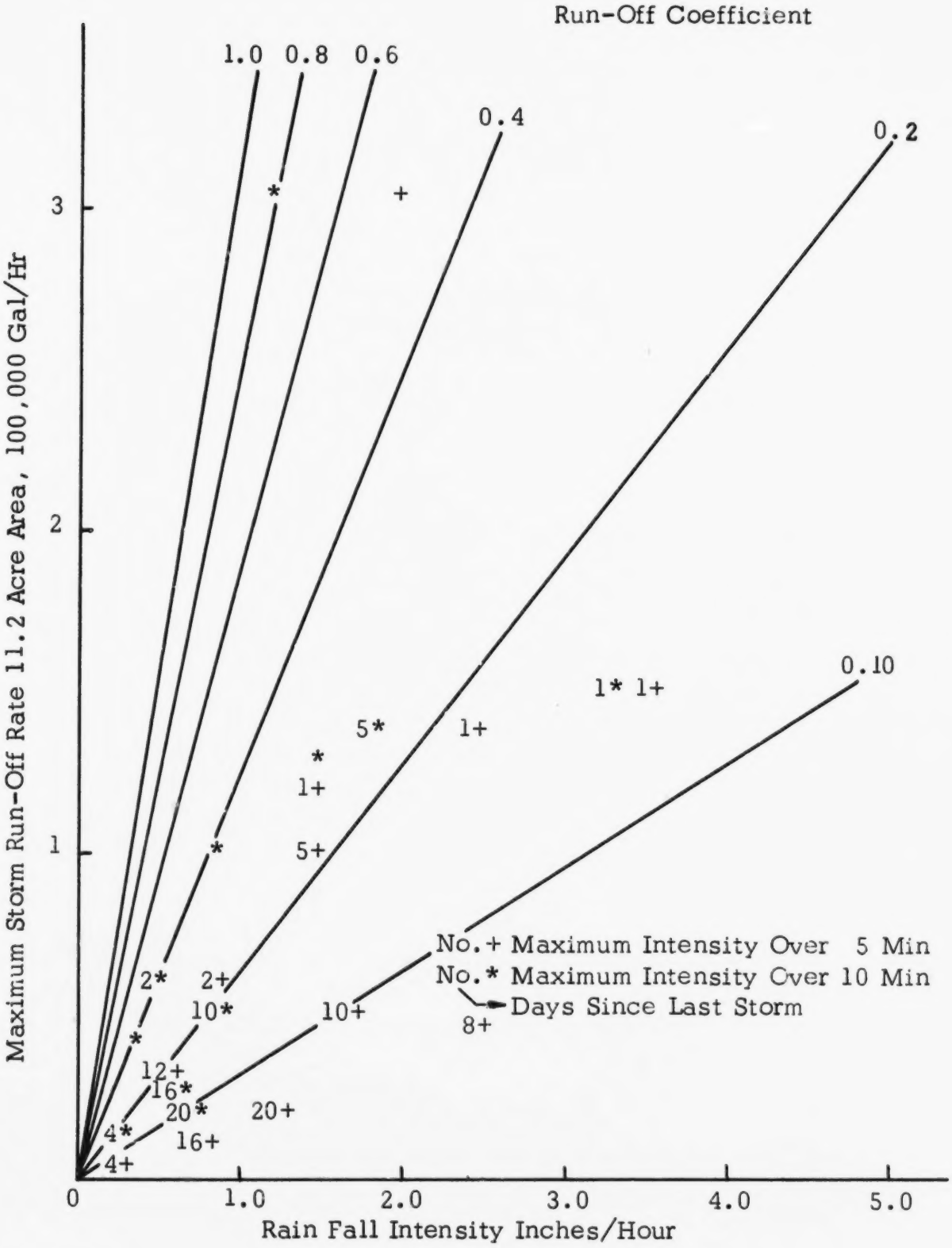
In 1969, 40 of 45 storms produced overflows in the order of 0.81 to 8.12 cfs, with rain intensities ranging from .12 to 3.3 inches per hour. It can be seen that the highest rainfall recorded during our work has been about 3.3 inches per hour for 10 minutes, but that the highest runoff coefficients (0.8) do not coincide with these periods. We also have shown, for some points in Figure 7, the intervals in days since the previous rainfall. These figures do not appear to be adequate for interpretation of the differences in the runoff coefficients.

The highest flow at which the combined sewer discharged into its receiving sump was thus approximately 300,000 gallons per hour (or about 11 cfs) for about 0.4 hours. The corresponding runoff coefficient was calculated at 0.5. The 11-acre area involved has an imperviousness factor of 61%.

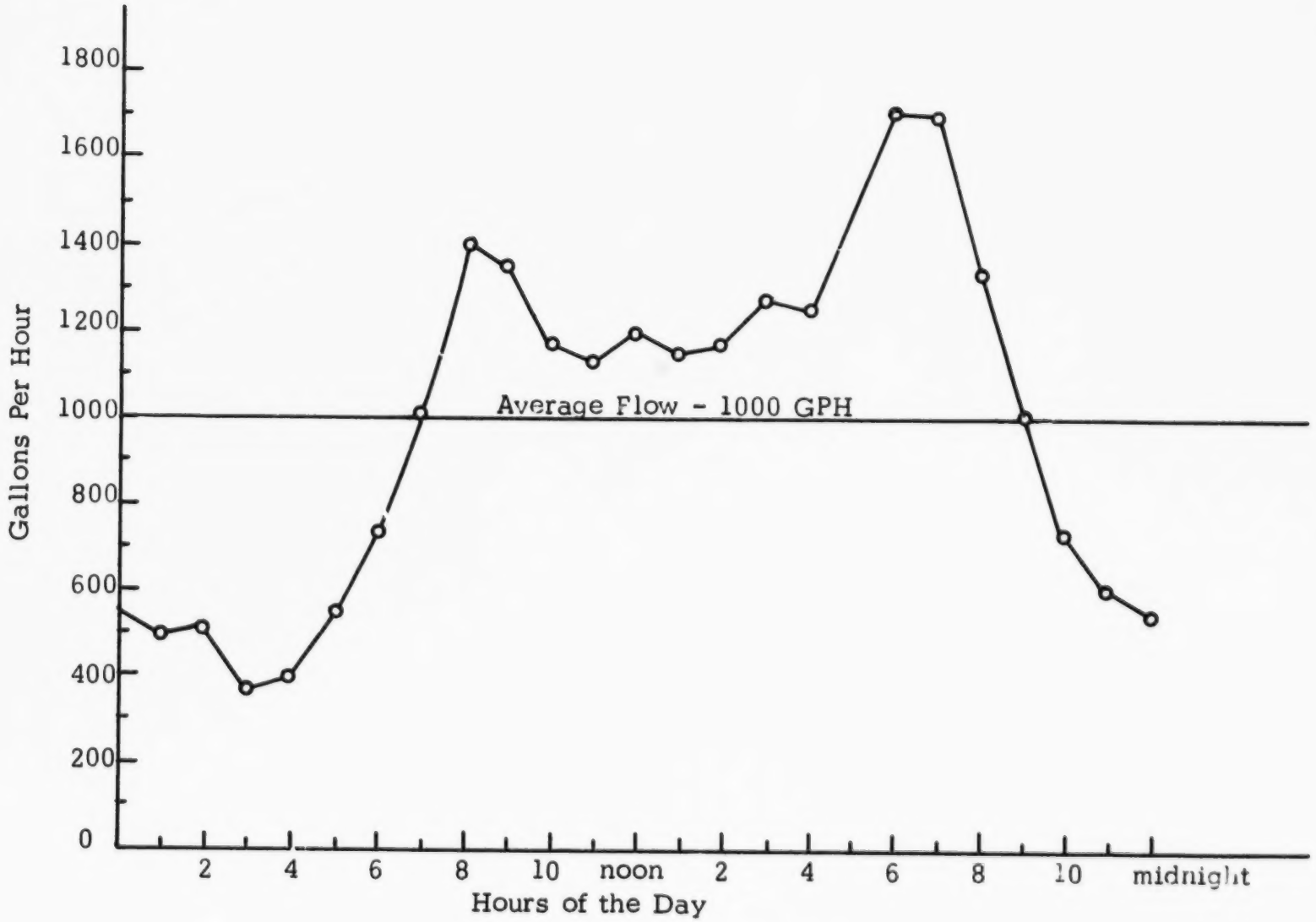
*4.8 inch dual traverse, 6 hours,
Universal Rain Gage, Belfort Instrument Co.



Rainfall Intensity 1903-1951
Philadelphia, Pennsylvania
Figure 6



Maximum Storm Run-Off Vs
Rain Fall Intensity (City of Philadelphia Data)
Figure 7



Hourly Variations, Sanitary Flow, 67th & Callowhill Sts. Sewer
(City of Philadelphia Data)
Figure 8

SECTION VI

COMBINED SEWER OVERFLOW QUALITY

As expected, our data show that within the capabilities of the samplers, the quality of the overflow tends to change with both the quantity and the duration of the rainfall. For example: in Table 1, for the storm of 7/23/69, it is seen that the suspended solids concentration of the Microstrainer influent was 55 ppm during the early storm period, increasing to 97 ppm at a second sampling, and then falling to a lower 21 ppm nearer the end of the last period. The same phenomena are shown for the storm of 7/28/69. Figure 9, which combines elements of both time and rainfall intensity, illustrates the relationship between overflow rate and suspended solids concentration, over a larger number of storms for which data are available. From this limited information there appears to be a direct relationship, but these data were accmulated over relatively short periods; and it would seem that, with high runoff intensities for longer periods, this relationship will not hold. Unfortunately, data for prolonged high flows are not available.

Fecal coliform analyses are generally higher at the beginning or toward the middle of a storm, and lower at the conclusion (Table 2). BOD results tend to follow the same course as the total suspended solids and volatile suspended solids for 7/28/69 and 9/3/69 (Table 3).

TABLE 1

SUSPENDED SOLIDS AND BOD, MICROSTRAINER INFLUENT, EFFLUENT

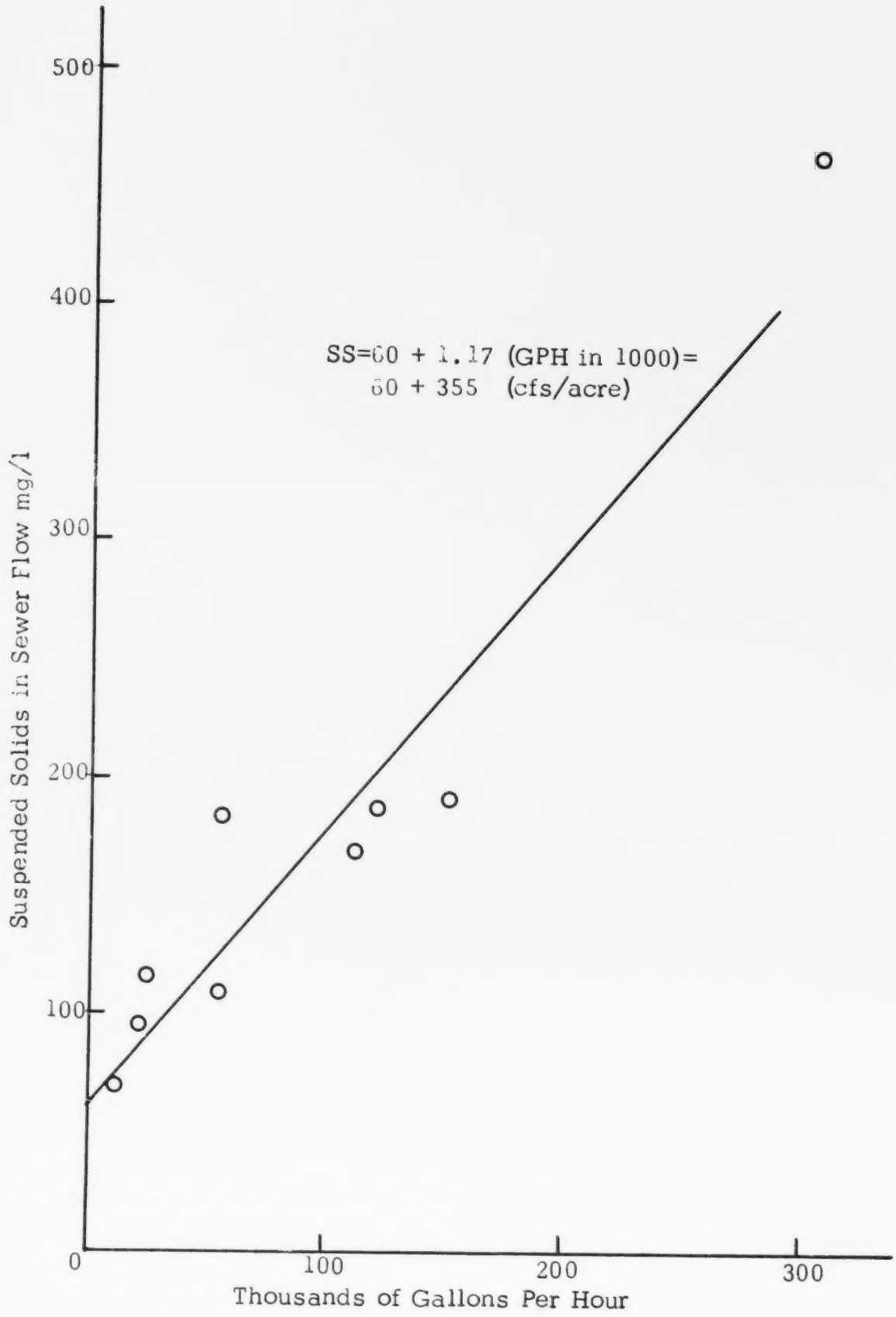
Date	Suspended Solids, mg/l			BOD, mg/l		
	In	Out	% Reduction	In	Out	% Reduction
MARK "I" SCREEN						
12-3-68	104	57	45	21	18	14
1-23-69	71	62	13	17	82+(1)	Incr
4-11-69	202	90	55	36	23	36
4-18-69	223	150	33	29	22	28
4-19-69	457	251	45	27	20	26
4-21-69	115	71	38	40	12	70
5-9-69	108	44	59	39	18	54
5-19-69	173	89	49	43	26	53
5-20-69	372	139	63	44	252+(1)	Incr
Average	203	106	44	33	20	-
MARK "0" SCREEN						
6-15-69	107	71	34	20	9	55
6-18-69	103	17	84	112	38	66
6-23-69	159	48	70	11	15	Incr
6-25-69	157	24	85	38	6	84
7-7-69	118	49	58	30	48	Incr
7-23-69	55	29	47	41	3	93
7-23-69	97	43	56	135	7	95
7-23-69	21	17	19	5	4	20
Average	102	37	57	49	16	-

TABLE 1 (continued)

SUSPENDED SOLIDS AND BOD, MICROSTRAINER INFLUENT, EFFLUENT

Date	Suspended Solids, mg/l In	Out	% Reduction	BOD, mg/l In	Out	% Reduction
MARK "0" SCREEN Control change, maximum differential increaded						
7-28-69	175	66	62	8	6	25
7-28-69	498	55	89	385+(1)	76	80
7-28-69	288	72	75	13	210+(1)	Incr
7-29-69	139	50	64	14	16	Incr
7-29-69	189	17	91	260	370+(1)	Incr
8-4-69	163	6	96	438+(1)	584+(1)	Incr
Average	242	44	80	74	33	-
MARK "0" SCREEN Filter Area Reduced						
9-3-69	111	2	98	135	740+(1)	Incr
9-3-69	419	17	96	740+(1)	208	72
9-3-69	69	15	78	13	45	Incr

(1) Dissolved O_2 in all dilutions was entirely depleted before the end of the five days and are not included in average.



Influence of Run-Off Rate on Suspended Solids
Figure 9

TABLE 2

FECAL COLIFORM[1]

Date	In	Out	After Chlorination 5 ppm-5min	After Chlorination 5 ppm-10 min	After Ozonation 3.8 ppm	Residual O_3, ppm
MARK "I" SCREEN						
12-3-68	330	655	-	-	-	-
1-23-69	1,300	900	-	-	-	-
4-11-69	510	670	5	-	-	-
4-18-69	1,610	1,630	-	-	-	-
4-19-69	1,460	1,940	-	-	-	-
4-21-69	690	5,700	-	-	-	-
5-9-69	9,000	8,800	100	670	140	-
			-	-	110	-
5-19-69	28,000	28,000	-	-	-	-
	1,500	2,500	-	-	33	1.9
5-20-69	3,000	4,800	-	-	0.2	1.3
	2,100	3,000	-	-	0.3	-

[1]Thousands per 100 ml

TABLE 2 (continued)

FECAL COLIFORM[1]

Date	In	Out	After Chlorination 5 ppm-5 min	After Chlorination 5 ppm-10 min	After Ozonation 3.8 ppm	Residual O_3, ppm
MARK "0" SCREEN						
6-15-69	13,400	6,200	77,000[2]	58	32,000[2]	1.6
			-	-	23,000[2]	-
6-18-69	4,400	2,600	77	0	44	1.9
			-	-	23	-
6-23-69	100	2,800	63	22	200	0.6
			-	-	57	-
6-25-69	6,700	590	91	8.4	5,700	1.3
			-	-	2,800	-
7-7-69	27,000	30,000	-	-	-	-
		11,000	0	1	6.8	-
			-	-	4.3	-
7-23-69	2,200	2,700	-	-	-	-
	3,700	810	-	-	-	-
	2,800	1,100	0.1	25	0.6	0

[1]Thousands per 100 ml

[2]Values not used in calculation of averages

TABLE 2 (continued)

FECAL COLIFORM[1]

Date	In	Out	After Chlorination 5 ppm-5 min	After Chlorination 5 ppm-10 min	After Ozonation 3.8 ppm	Residual O_3, ppm
MARK "0" SCREEN						
Controls changed to produce fixed relation between differential and drum speed. Maximum differential increased						
7-28-69	240	190	-	-	-	-
	120	0	-	-	-	-
		11	0.5	5.4	0.6	0.3
			-	-	1.8	-
		0	76	25	7	-
			-	-	2.6	-
	25	31	-	-	17	-
			-	-	19	-
7-29-69	5	90	-	-	-	-
	110	120	-	-	-	-
8-4-69	200	18	0	0	2.3	0.6
			-	-	25	-

[1]Thousands per 100 ml

TABLE 2 (continued)

FECAL COLIFORM[1]

Date	In	Out	After Chlorination 5 ppm-5 min	After Chlorination 5 ppm-10 min	After Ozonation 3.8 ppm	Residual O_3, ppm
SCREEN FILTERING AREA REDUCED						
9-3-69	5,200	3,900	-	-	-	-
	7,300	6,000	-	-	-	-
	2,600	3,800	-	-	-	-

[1]Thousands per 100 ml

TABLE 3

VOLATILE SUSPENDED SOLIDS, MICROSTRAINER

Date	mg/l In	Out	% Reduction
MARK "I" SCREEN			
12-3-69	60	60	0
1-23-69	33	27	18
4-11-69	41	21	49
4-18-69	63	38	40
4-19-69	111	52	53
4-21-69	44	22	50
5-9-69	51	21	59
5-9-69	69	27	61
5-19-69	79	38	52
5-19-69	42	20	52
5-20-69	90	30	67
5-20-69	42	17	60
Average	60	31	47

TABLE 3 (continued)

VOLATILE SUSPENDED SOLIDS, MICROSTRAINER

Date	mg/l In	Out	% Reduction
MARK "0" SCREEN			
6-15-69	34	12	65
6-18-69	35	4	89
6-23-69	31	12	61
6-25-69	81	8	90
7-7-69	53	28	47
7-23-69	21	7	67
7-23-69	39	13	67
7-23-69	9	4	56
Average	38	11	68
MARK "0" SCREEN - Controls Changed			
7-28-69	37	9	76
7-28-69	63	13	79
7-28-69	48	22	46
7-29-69	44	19	57
7-29-69	38	9	76
8-4-69	54	3	94
Average	47	12	71

TABLE 3 (continued)

VOLATILE SUSPENDED SOLIDS, MICROSTRAINER

Date	mg/l In	Out	% Reduction
MARK "0" SCREEN - Area Reduced			
9-3-69	21	9	57
9-3-69	42	7	83
9-3-69	18	5	72
Average	27	7	71

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SECTION VII

MICROSTRAINING RESULTS

Total Suspended Solids

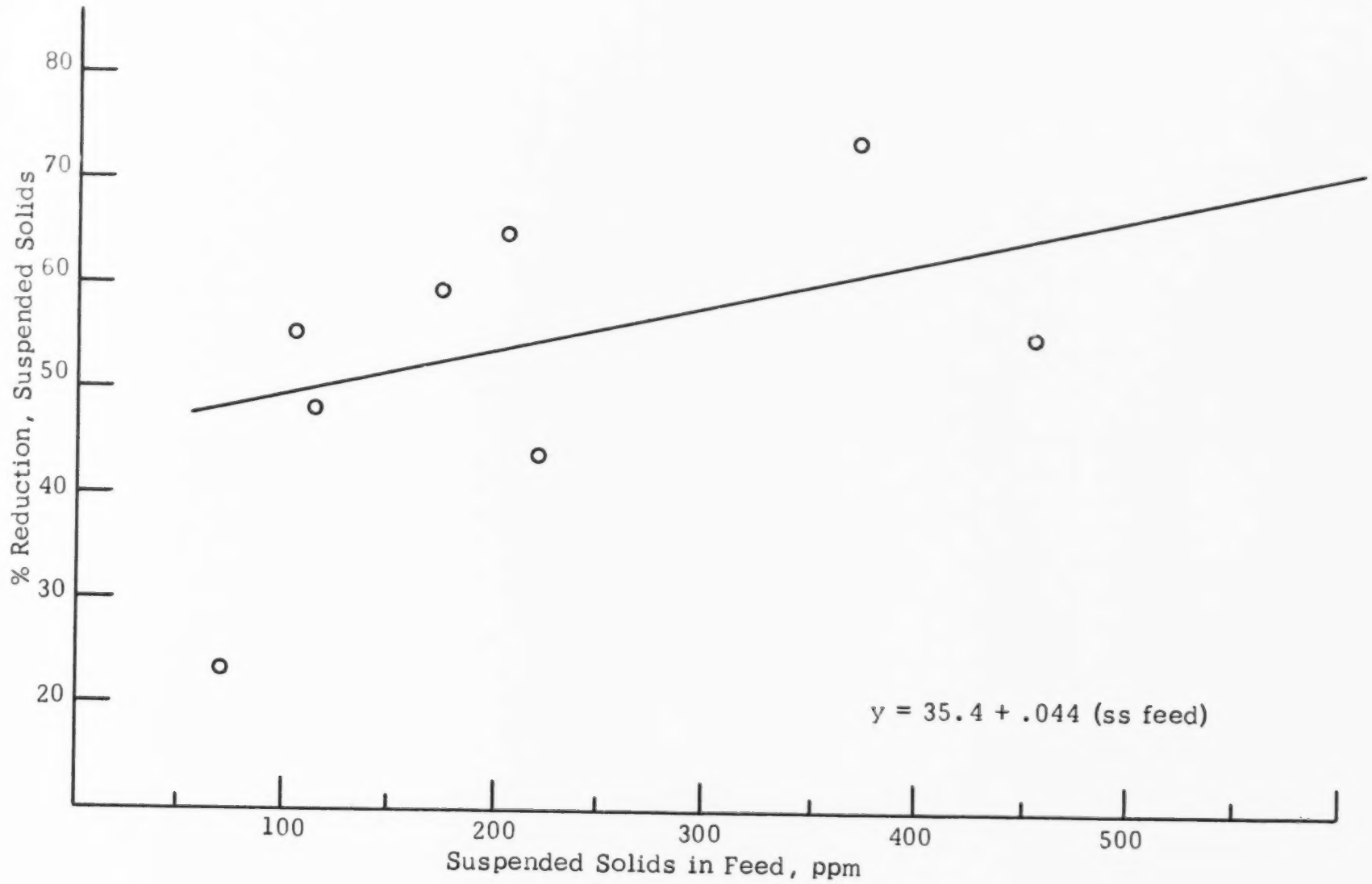
As initially installed, the Microstrainer was fitted with the Mark "I" screen, with a nominal aperture size of 35 microns. As work progressed, it became evident that the backwash jets, in conjunction with slime prevention by means of ultraviolet light, would prevent plugging and fouling of the screen, and that the influents that were received could be more than adequately handled. Accordingly, after about 6 months of operation, the finer Mark "0" screen was installed, to determine if increased quality of the effluent could be realized without pluggage.

Furthermore, after an additional 2 months of operation, the Microstrainer controls were altered to provide a drum speed more closely related to differential head. And finally, 80% of the filter screen area was blanked off by inserting plastic film inside the screen. At the same time, the backwash jets normally serving the blanked-off area were turned off.

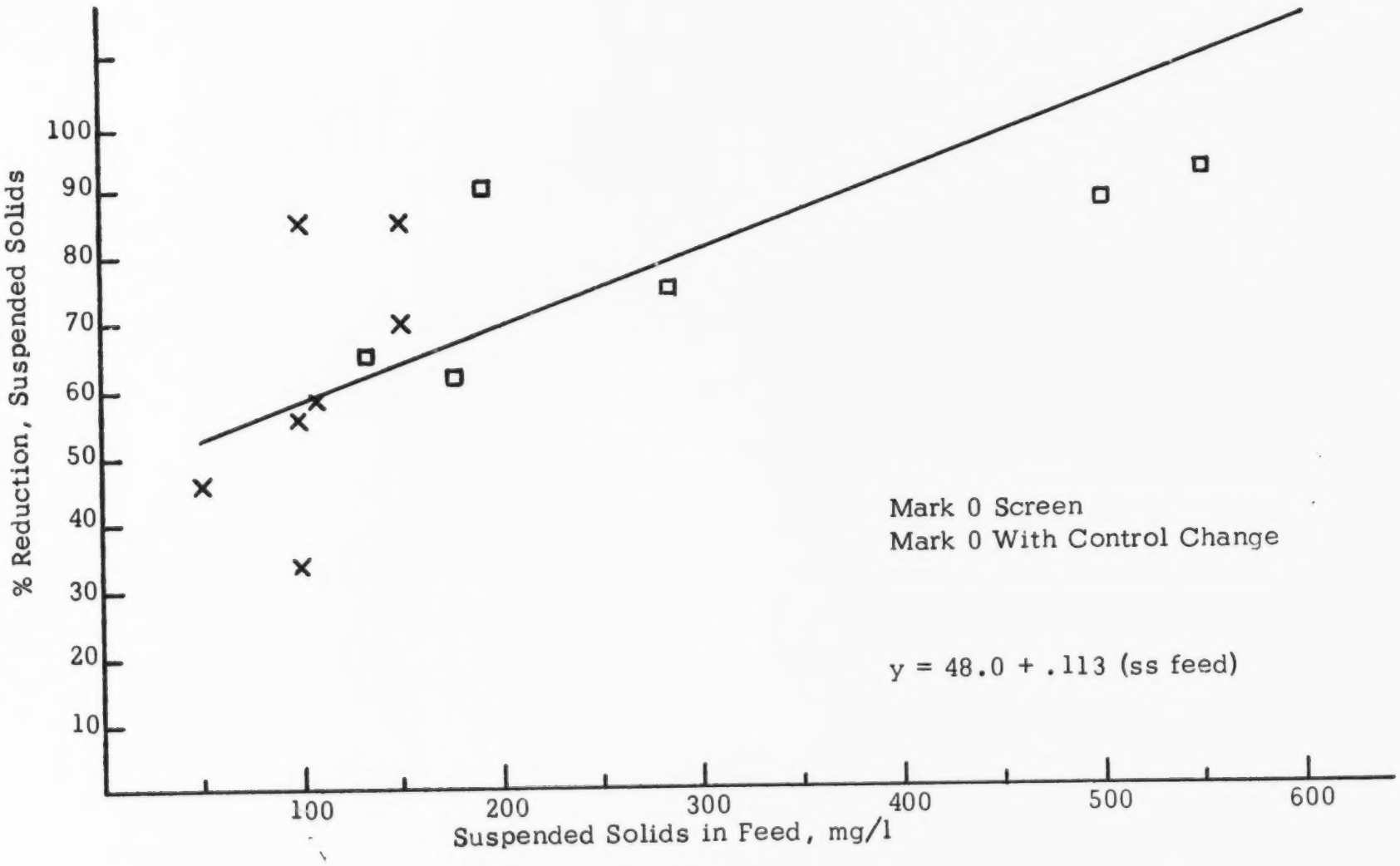
These last-named steps were taken to increase the Microstrainer hydraulic loading and to determine the effects of this increase on the quality of the effluent. An increase in hydraulic rating would correspondingly reduce capital cost of a full-scale installation.

As can be seen in Table 1 and Figures 10, 11 and 12, the removals of total suspended solids ranged from 13% to 98%, the higher values being characteristic of the Mark "0" screen and better-regulated drum speeds. Although the data are scattered, regressions are shown for suspended solids in the feed vs % reduction of suspended solids, in Figure 10 and 11. These illustrate the improvement in performance gained through the use of the Mark "0" screen, and also show the tendency for increased removal efficiency with an increase in the influent suspended solids concentration. For the amount of data acquired, straight line regressions offered a reasonable fit.

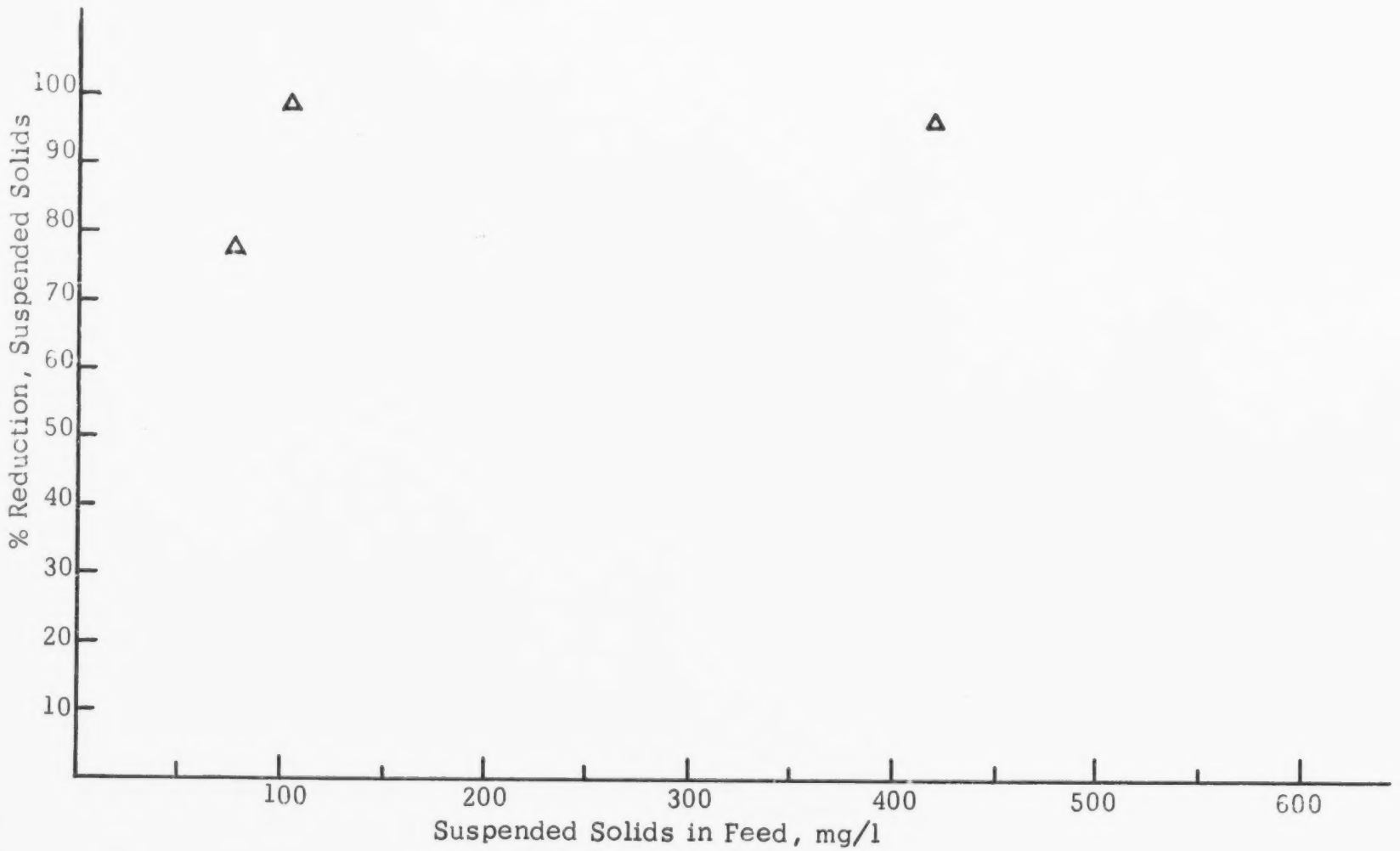
The results for removal of volatile suspended solids are shown in Table 3 and Figure 13. These results parallel those for total suspended solids, about an average value of 71% removal for the Mark "0" screen and the higher differentials.



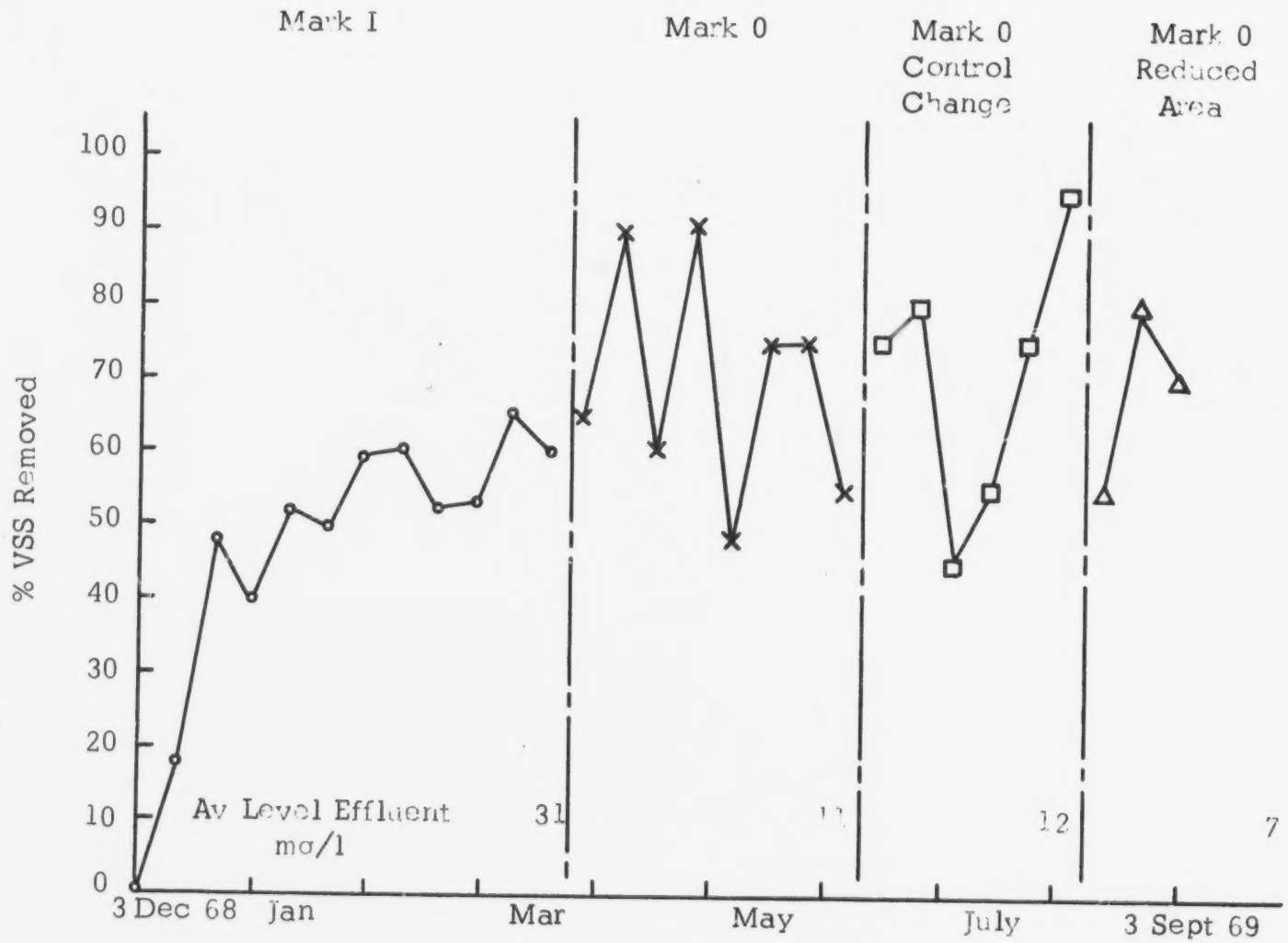
Suspended Solids Reduction
Mark I Screen
Figure 10



Suspended Solids Reduction
Mark 0 Screen
Figure 11



Suspended Solids Reduction
Mark 0 Screen, Reduced Area
Figure 12



Volatile Suspended Solids Removal - Microstrainer
Figure 13

BOD

Removals of BOD are scattered (Table 1, Figure 14).

It is postulated that the volatile suspended solids that pass the screens are in a much more finely divided form. It is further suggested that the resulting increased surface area of these solids may serve as a more rapid and more efficient growth medium for bacteria. It is thus probable that downstream effects, after Microstraining, will be less persistent, particularly in view of the major reduction in volatile suspended solids. Moreover, it appears certain that post-treatment with chlorine or ozone, if practiced, should produce markedly better disinfection, considering the reduction in the number of larger particles that tend to occlude organisms, protecting them from the action of these treatments.

Fecal and Total Coliform

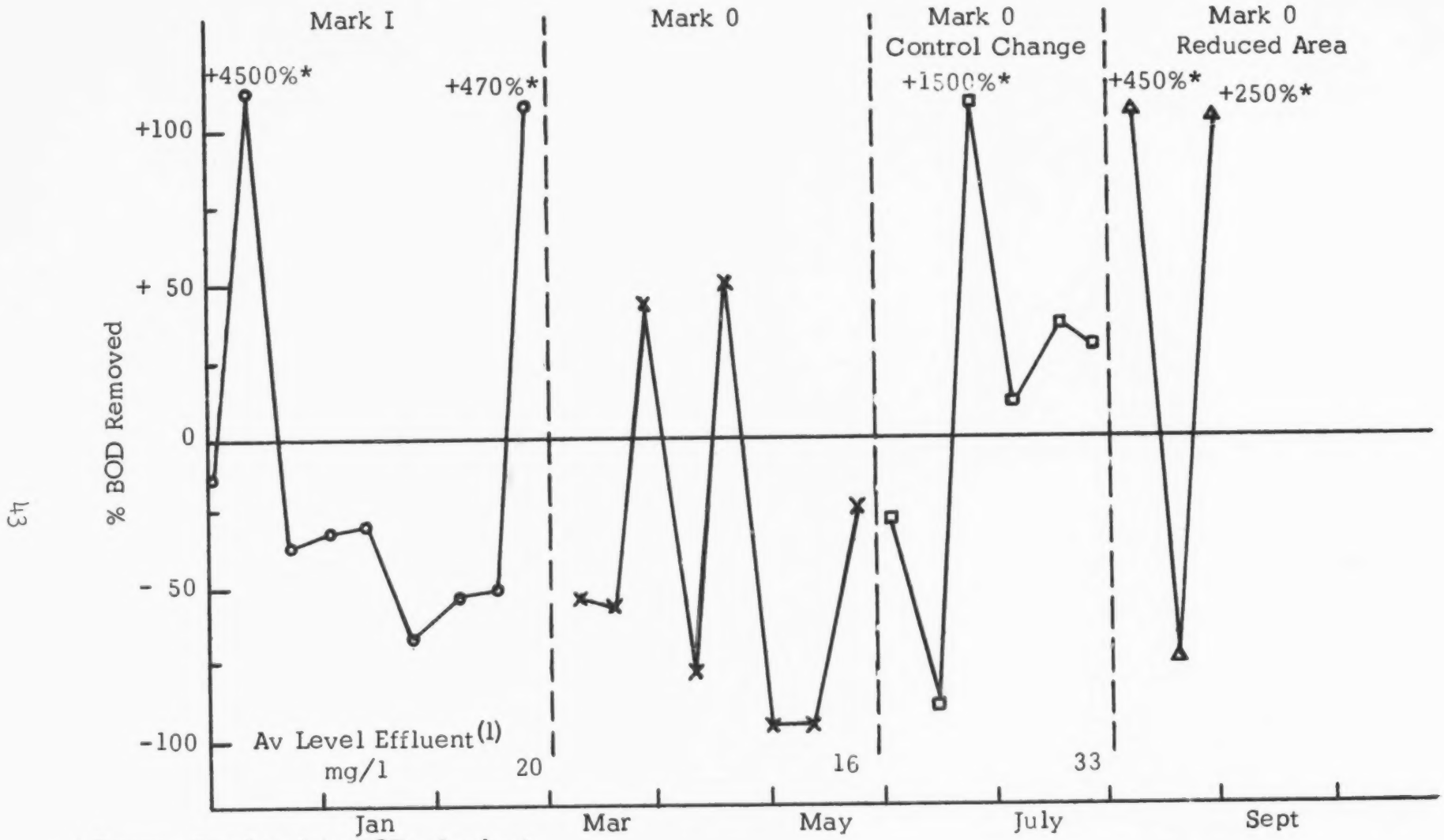
As shown in Tables 2 and 4, both fecal and total coliform bacteria analyses quite frequently show increases in concentrations in the Microstrainer effluent. This phenomenon has previously been noted by Boucher[10]. Clearly, no net "removal" of these organisms can be claimed on the basis of these results. However, several postulations have been made for these observed increases:

1. Natural predators are largely removed by Microstraining and are thus not present in large numbers on the discharge side.

2. Large clumps of material rich in bacteria are fragmented into numerous smaller particles by passing through the screen.

3. The bacterial food supply is similarly made more available by the screening process, and the growth rate during the 5-day measurement period is enhanced.

As related above, we have tended to accept the last-named postulation, but it must be emphasized that the question has not been resolved. A complicating factor is the report from the Philadelphia Research Group that on one occasion predators (paramecia) were absent from the Microstrainer discharge sample, while they were present in the influent sample. These last results were obtained at the end of the program, and confirmation was not possible.



*Oxygen Depleted in BOD_5 Analysis
(1) Do Not Include * Data Points

BOD Removals - Microstrainer
Figure 14

TABLE 4

TOTAL COLIFORM[1]

Date	In	Out	After Chlorination 5 ppm-5 min	After Chlorination 5 ppm-10 min	After Ozonation 3.8 ppm	Residual O_3, ppm
MARK "I" SCREEN						
12-3-68	666	740	-	-	-	-
1-23-69	1,607	1,280	-	-	-	-
4-11-69	720	840	3	6	-	-
4-18-69	2,600	2,970	-	-	-	-
4-19-69	2,310	2,380	-	-	-	-
4-21-69	1,310	9,800	-	-	-	-
5-9-69	10,300	8,500	800	760	-	-
			-	-	330	-
5-19-69	100,000	93,000	-	-	580	-
	8,700	4,000	-	-	-	
5-20-69	2,700	3,600	-	-	33	1.9
	5,200	6,700	-	-	0.2	1.3
					0.4	-

[1]Thousand per 100 ml

TABLE 4 (continued)

TOTAL COLIFORM[1]

Date	In	Out	After Chlorination 5 ppm-5 min	After Chlorination 5 ppm-10 min	After Ozonation 3.8 ppm	Residual O_3, ppm
MARK "0" SCREEN						
6-15-69	19,900	8,600	98,000[2]	130	60,000[2]	1.6
			-	-	36,000[2]	-
6-18-69	8,600	5,900	290	0	100	1.9
			-	-	120	-
6-23-69	1,200	14,000	240	79	500	0.6
			-	-	220	-
6-25-69	10,000	860	150	18	7,600	1.3
			-	-	3,900	-
7-7-69	28,000	11,000	5.1	100	18	-
			-	-	13	-
7-23-69	1,800	1,100	0.2	110	4.8	0

[1]Thousand per 100 ml

[2]Values not used in calculation of averages

TABLE 4 (continued)

TOTAL COLIFORM[1]

Date	In	Out	After Chlorination 5 ppm-5 min	After Chlorination 5 ppm-10 min	After Ozonation 3.8 ppm	Residual O_3, ppm
MARK "0" SCREEN						
Controls changed to produce fixed relation between differential and drum speed. Maximum differential increased						
7-28-69	170	0	330	200	30	-
			-	-	8	-
	44	11	0.8	12	0.5	0.3
			-	-	5.4	-
	78	200	-	-	-	-
		31	-	-	100	-
			-	-	23	-
7-29-69	130	330	-	-	-	-
	150	230	-	-	-	-
8-4-69	15	8	0	0	3.8	0.6
			-	-	32	-

[1] Thousands per 100 ml

TABLE 4 (continued)

TOTAL COLIFORM[1]

Date	In	Out	After Chlorination 5 ppm-5 min	After Chlorination 5 ppm-10 min	After Ozonation 3.8 ppm	Residual O_3, ppm
SCREEN FILTERING AREA REDUCED						
9-3-69	12,000	16,000	-	-	-	-
	20,000	13,000	-	-	-	-
	12,000	20,000	-	-	-	-

[1]Thousands per 100 ml

Sampling and Analysis

Early in the program, when apparent inconsistencies were observed in the BOD and bacterial results, the sampling and analysis procedures were reviewed by project personnel. COD analyses were also performed on several samples by the City Northeast Laboratory Group, during this early period, and these measurements confirmed the BOD results. The sampling location for the discharge side of the Microstrainer was ultimately changed to a point about 1 to 2 inches from the screen, and close attention was paid to sample handling and analysis procedures. As noted above, these apparent inconsistencies were not eliminated and the postulations concerning BOD and coliform test results are made as possible explanations.

It should be emphasized that suspended and volatile solids analyses from the same samples were not inconsistent, and these latter results lend support to sample validity.

Nonetheless, it must be recognized that these problem areas, intensified by the intermittent operation involved, do exist. And special care is required to validate performance.

SECTION VIII

CHLORINATION AND OZONATION

Average total coliform concentrations for the final effluents in all of our work, under varying conditions imposed on the Microstrainer, using 5 ppm of chlorine for 5 and 10 minute retention times, were 166,000 per 100 ml and 129,000 per 100 ml, respectively. For fecal coliform concentrations, these values, in the same order, were 41,000 and 81,000. Similar results for ozone at a concentration of 3.8 ppm and a detention time of about 12 minutes were 619,000 and 42,000. The corresponding total coliform results for the Microstrainer effluent (prior to chemical treatment) ranged from zero (in one instance) to a high of 93,000,000, and the fecal coliform counts ranged from zero to 30,000,000.

Ozone, of course, is more desirable for color removal, or in those cases where a less stable, less persistent chemical residual is needed (chloramines may be both persistent and toxic to fish in the receiving water).

Higher chemical feed and/or longer detention times are needed for a more complete bacterial kill. In this treatment situation it is obvious that the former is more economical because of the increased cost of storage for detention. Whether additional disinfection time would be available in the outfall line and receiving water downstream of an actual plant of this type would depend on individual circumstances.

Table 5 gives average values of coliform concentrations in the final effluent.

Time has permitted a limited amount of investigation of larger dosages of chemicals and shorter detention times, and some results with chlorine* indicate that greater bacterial kills may be attained in this way. For example: in one test on different portions of the same sample, total coliform counts were 110,000 per 100 ml for 10 ppm dosage and 2 minutes reaction time, and 7,500 per 100 ml for 15 ppm and 2 minutes.

*These last-acquired results are not listed in any of the Tables.

TABLE 5

TOTAL COLIFORM, FINAL EFFLUENT
AVERAGE VALUES
(Thousands per 100 ml)

CHLORINATION (5 ppm)		OZONATION (3.8 ppm)
5 min	10 min	
166	129	619

FECAL COLIFORM, FINAL EFFLUENT
AVERAGE VALUES
(Thousands per 100 ml)

CHLORINATION (5 ppm)		OZONATION (5 ppm)
5 min	10 min	
41	81	42

It is suggested that short detention times may be much more effective for effluents from the small-aperture Microstrainer screen, because of the fine state of subdivision of the particulate matter, which escapes the straining process. Organisms are less likely to be shielded from chemical attack by occlusion than in the larger particulates characteristic of many other processes.

SECTION IX

ECONOMICS

The best solution for the combined-sewer-overflow problem appears to vary with individual circumstances[7]. Among the determining circumstances are the character of the existing collection system, nature of the receiving water, population density, rainfall, land use factors (i.e., residential, commercial, industrial), topography, and size of the catchment area.

In many cases, it would appear that large land areas required for holding basins are not available. And in some cases, the prospect of retaining large volumes of combined sewage for discharge at low rates to the sewer system and a disposal plant would appear unattractive from both aesthetic and practical standpoints.

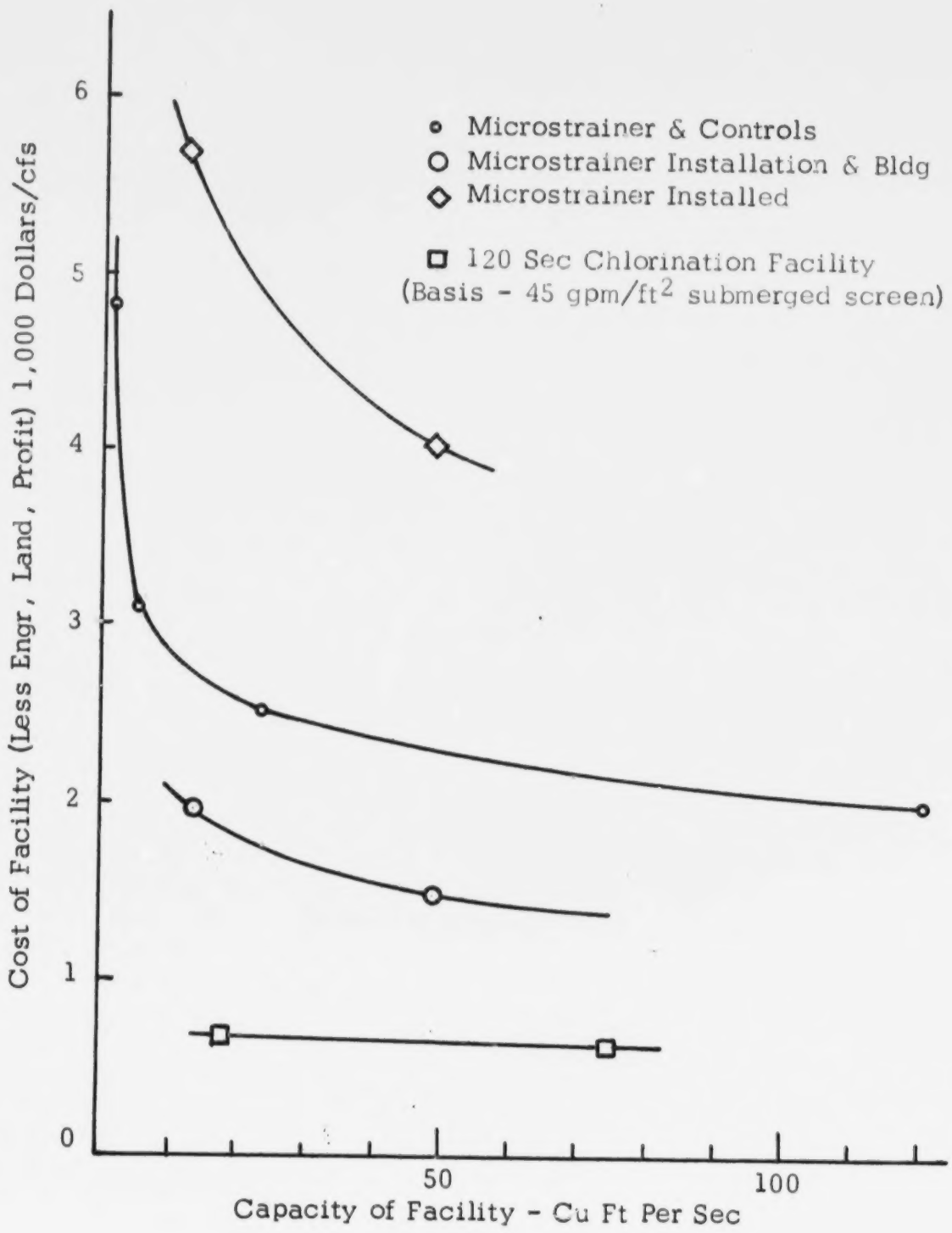
Large detention basins, such as have been mentioned for Columbus, Ohio, and Boston, Mass.[6], will presumably sometimes be employed where huge overflow volumes are involved. But in instances where large amounts of land are not available, or ultimate disposal is difficult, or where the local environment is not suitable for detention-tank installation, the Microstrainer should be considered.

In this connection, a recent publication[11] points out that 25% of the catchment areas in Washington, D.C., are 25 acres or less in size, and that a similar survey of Milwaukee, Wis., revealed that 50% of these areas are of 25 acres or less. There is no intent to imply that the use of Microstraining should be limited to the smaller areas, but these figures illustrate the number of smaller subdivisions of a drainage basin that might be handled locally.

The cost analysis below illustrates approximate costs for Microstraining, and for other suggested processes, in a drainage area of the type used in this program.

Projected Capital Cost of High-Rate Microstrainer and Chlorination Facility

To help illustrate the applicability of the Microstraining and chemical disinfectant techniques for combined sewer overflows, projected costs of a facility have been developed. Figure 15 and Table 6 show capital



Microstrainer-Chlorination Capital Costs
Figure 15

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TABLE 6

CAPITAL COST OF COMBINED SEWER OVERFLOW TREATMENT SCHEMES
(10 mgd plants)

Scheme No.	Train of Steps in Scheme	Capital Cost of Treatment Step $ per mgd	Capital Cost of Scheme Less Land and Engineering $ per mgd	$ per cfs	$ per acre
1	Separate storm sewer, no treatment of storm water.	ND*	17,000	11,000	23,000
2	Surface impounding basin, low rate repumping station.	ND	5,100	3,300	6,500
	Sewage plant addition.	ND	ND	ND	ND
3	Sub-surface impounding basin, low rate repumping station.	ND	19,500	12,500	25,000
4	Equalizing basin (5 min)	1,000(1)			
	Primary clarifier	6,000(2,3)			
	High rate "Bio-Disc", including secondary clarifier	25,000(2,4)			
	Conventional chlorine contact	1,000(2,3)	33,000	21,400	42,000
5	Equalizing basin (5 min)	1,000(1)			
	Primary clarifier	6,000 (2,3)			
	High rate aeration	25,000(2,4)			
	Secondary clarifier	4,000(3,5)			
	Conventional chlorine contact	1,000(2,3)	37,000	24,000	47,000

*Not Determined

TABLE 6 (continued)

CAPITAL COST OF COMBINED SEWER OVERFLOW TREATMENT SCHEMES
(10 mgd plants)

Scheme No.	Train of Steps in Scheme	Capital Cost of Treatment Step $ per mgd	Capital Cost of Scheme Less Land and Engineering $ per mgd	$ per cfs	$ per acre
6	Equalizing basin	1,000(1)			
	Wet cyclone	2,500(6)			
	Dissolved air flotation	6,650-11,650(7)			
	Conventional chlorine contact	1,000(2,9)	10-15,000	7-10,000	13-19,000
7	Equalizing basin	1,000(1)			
	Fine screen	1,350(8)			
	Dissolved air	6,650-11,650(7)			
	Conventional chlorine contact	1,000(2,9)	9-14,000	6- 9,000	12-18,000
8	Primary clarifier	6,000(2,3)			
	Carbon and polymer feeders	1,000(1)			
	Carbon re-activation furnace	4,000(8)			
	Conventional chlorine contact	1,000(2,3)	12,000	7,800	15,500
9	Bar screen and 45 gpm/ft^2 Microstrainer	7,950(9)			
	2-minute chlorine contact chamber with hypochlorite feeder	900(9)	8,850	5,700	11,200

TABLE 6 (continued)

CAPITAL COST OF COMBINED SEWER OVERFLOW TREATMENT SCHEMES
(10 mgd plants)

Scheme No.	Train of Steps in Scheme	Capital Cost of Treatment Step $ per mgd	Capital Cost of Scheme Less Land and Engineering $ per mgd	$ per cfs	$ per acre
10	Bar screen and 45 gpm/ft^2 Microstrainer	7,950(9)			
	2-minute ozone contact chamber with once-thru oxygen fed ozone generator	7,700(9)	15,650	10,100	19,800

(1) Estimate
(2) Pre-publication copy of FWQA Contract Report 14-12-462.
(3) Assumption that conventional sewage equipment might have a stormwater capacity three times its rated capacity in normal sewage service.
(4) Private communication: W. Torpey, regarding minimum anticipated relative cost of high rate to conventional biological equipment; i.e., one-fifth of cost on a maximum flow capacity basis.
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(6) O.F. Tangle and R.J. Brinson, "Wet Cyclones", Chem Engr, June 1955.
(7) D.G. Mason, "The Use of Screening/Dissolved Air Flotation for Treating Combined Sewer Overflow", FWQA Combined Sewer Overflow Seminar, Edison, New Jersey, November 5, 1969.
(8) Manufacturers' quotations.
(9) This work.

costs for such facilities. These costs are based on the assumption that the Microstrainer will treat 45 gpm (0.1 cfs) of the overflow water under consideration, per square foot of submerged screen area. Further, they are based on the assumption that an adequate bacterial kill can be accomplished in a suitably configured detention chamber of only 2 minutes residence time. The observations recorded in earlier sections of this report indicate that these assumptions are reasonable.

To make this scheme as generally applicable as possible, the head loss of the water flow through the entire facility is limited to 4 feet. Two feet of the loss will occur in the Microstraining and inlet section containing the bar screen. The provision for 2 feet head loss in the chlorination section is to insure adequate turbulent mixing. Since it is anticipated that the overflow facility will not be sized large enough to treat the once-in-ten-year storm, provision has been made to bypass a flow equal to the Microstrainer capacity while the Microstrainer is in operation. Thus the facility can accept twice the design capacity, treat half and bypass the remainder, without interfering with operation. Design in an actual case would depend on local hydrology.

The dollar benefit to society from the reduction of pollution by combined sewer overflows has not been established. The assignment of such a benefit value is beyond the scope of this work. Thus, the cost of Microstraining treatment of combined sewer overflows cannot be compared to the value of the benefit. However, the estimated cost of Microstraining can be compared to the approximate costs of other methods of treatment.

Capital Cost of Combined Sewer Overflow Treatment Schemes

At a recent symposium[12] on treatment of combined sewer overflows, some nine treatment schemes were discussed. These schemes consisted of combinations and modifications of 12 basic treatment steps. To compare the costs of these schemes, approximate costs have been developed for the individual steps. Further, the capital costs of the treatment steps have been expressed in terms of dollars per unit of capacity, in combined-sewer-overflow service. At the present stage of knowledge regarding both the effluent quality required and the capabilities of these techniques in this service, some broad assumptions had to be made.

Figures 16a through 16i show schematically the treatment schemes under consideration. Table 6 lists the steps required in each scheme, and the estimated price per mgd of capacity. As noted in the references to this table, conventional sewage treatment processes such as primary clarification, trickling filter, conventional chlorination, etc., have been assumed to be capable of treating three times their nominal sewage service capacity when used in combined-sewer-overflow service.

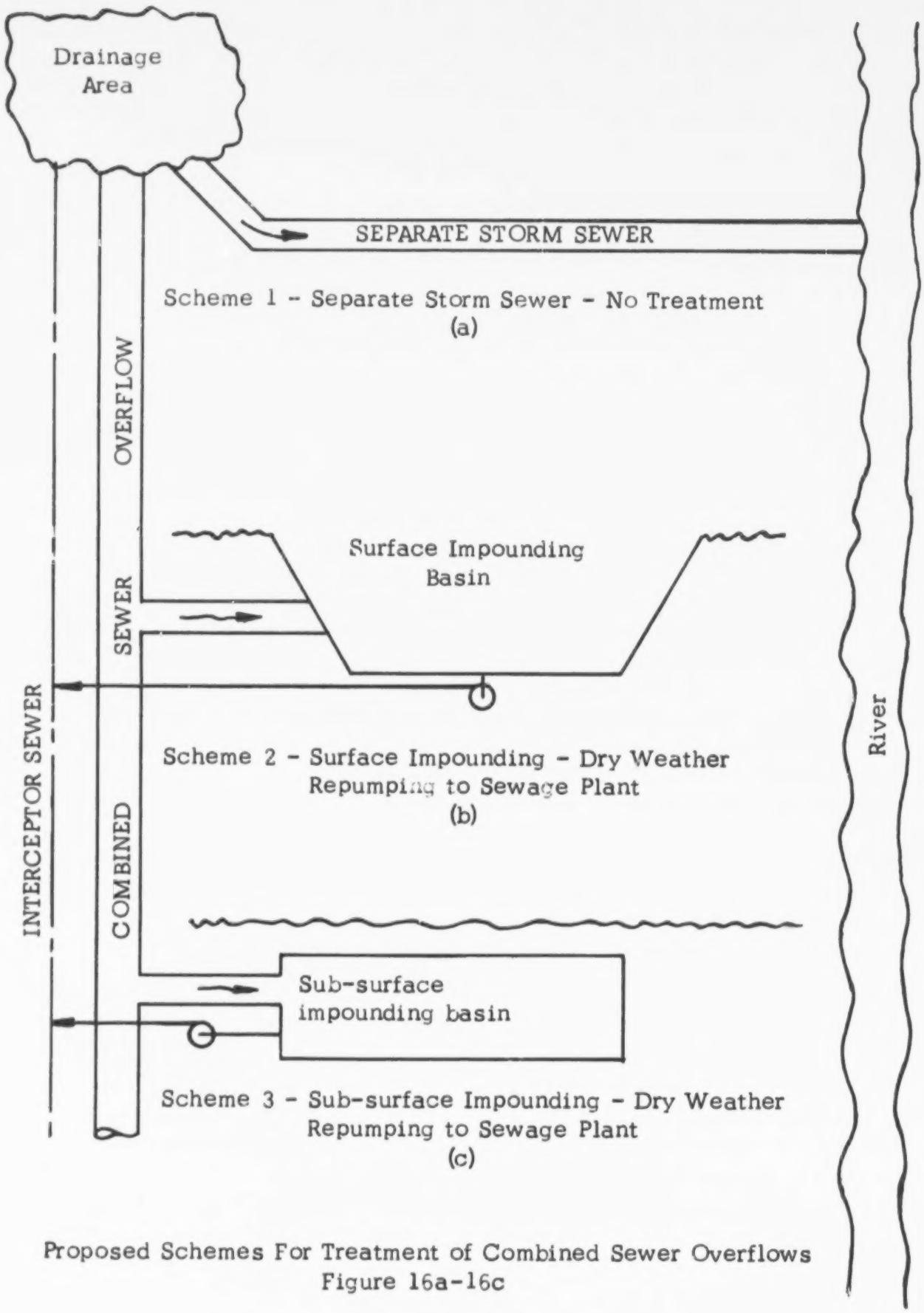
Advanced biological treatment processes such as rotary Bio-Disc, ultra-high-rate activated sludge, etc., have been assumed to have a capacity such that the capital cost per unit of overflow capacity will be one-fifth that of comparable conventional biological equipment per unit of conventional sewage capacity.

The advanced non-biological treatment processes such as fine screens, wet cyclones, etc., have been developed from manufacturers' reported costs.

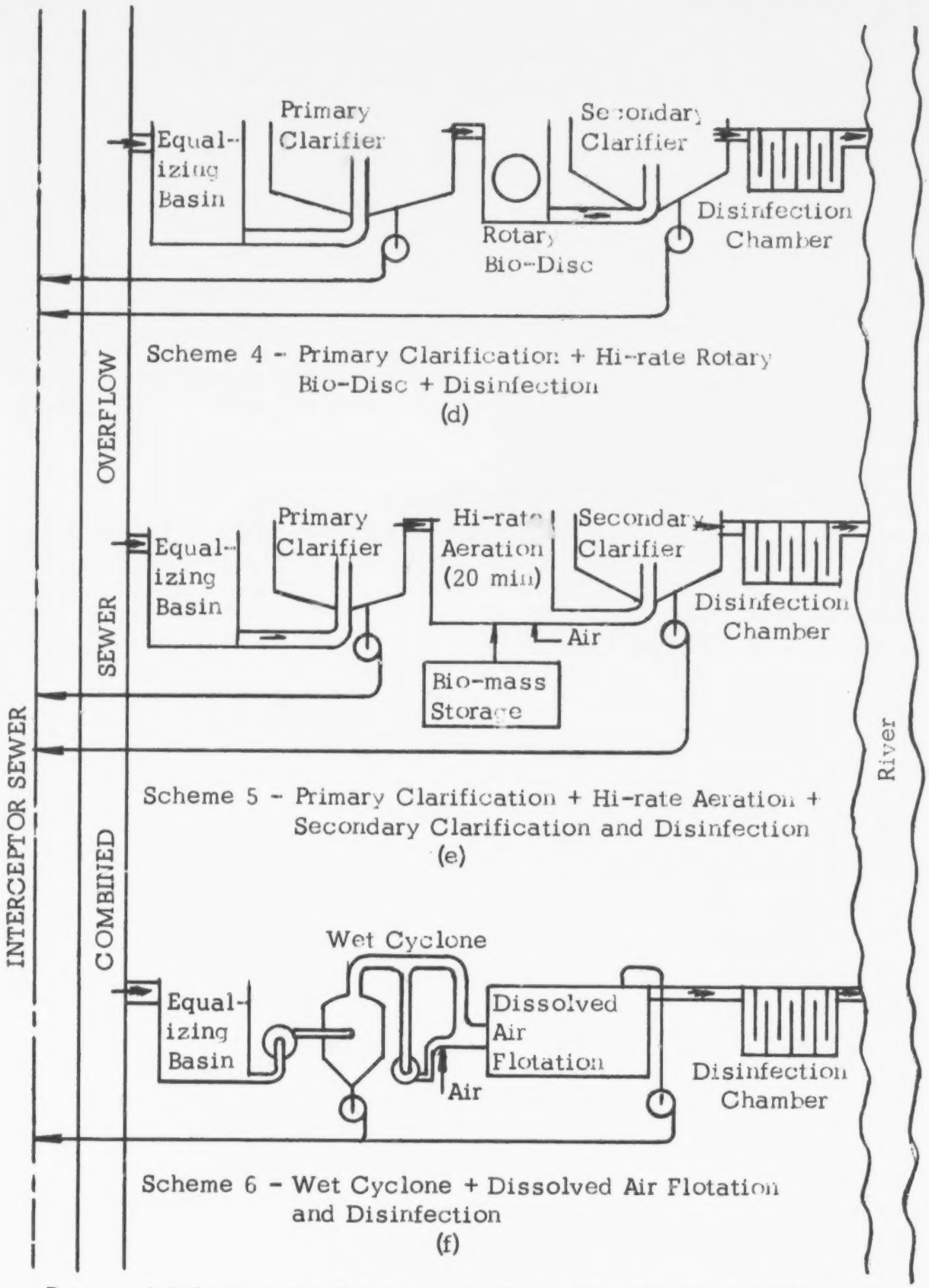
All reported costs were scaled to 1969 dollars and then to 10 mgd of nominal capacity. This scaling of the conventional steps of sewage treatment to 10 mgd nominal sewage capacity, together with the assumption that equipment with 10 mgd nominal sewage capacity is capable of 30 mgd combined-sewer-overflow capacity, introduced an inconsistency. The error favors the conventional equipment, since the comparison on a dollar cost-per-mgd capacity is made from a base of 30 mgd in case of conventional equipment and 10 mgd for the advanced treatment equipment. In general, all of the assumptions made favor the conventional and advanced biological steps.

The capital costs as noted in Table 6 include equipment procurement, equipment installation, and building, but do not include land or engineering fees. The land required for the various schemes covers a very wide range, from 0.03 acre per acre of drainage area in the case of surface impounding (Scheme 2) to less than 0.0002 acre per acre of drainage area in the case of Microstraining-chlorination (Scheme 9).

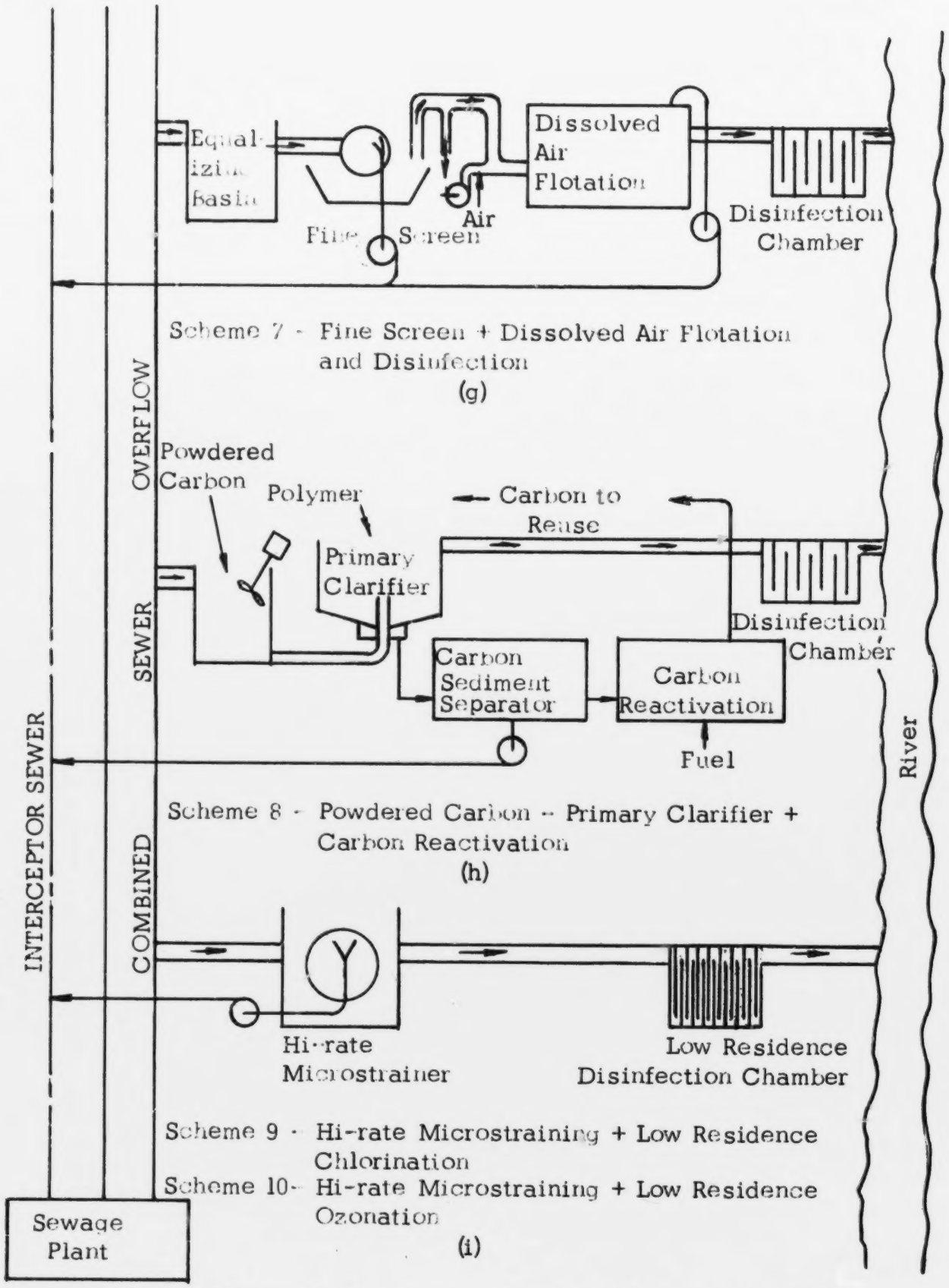
The capital costs of combined sewer overflow treatment facilities shown in Table 6 were developed on a dollar per mgd basis and converted to dollars per cfs basis (1 mgd - 1.54 cfs), and also to dollars per acre of drainage area on the assumption that 1.96 cfs was an adequate provision for overflow from an acre of drainage area.



Proposed Schemes For Treatment of Combined Sewer Overflows
Figure 16a-16c



Proposed Schemes For Treatment of Combined Sewer Overflows
Figure 16d-16f



Proposed Schemes For Treatment of Combined Sewer Overflows
Figure 16g-16i

The cost of surface impounding reported by Bannister[3] at $6,500 per acre for a 95-acre drainage area was not scaled to a 10 mgd base. This surface impounding facility at Chippewa Falls, Wis., made use of a fortunate set of circumstances, such as available, very-low-cost land adjacent to the drainage area, an existing interceptor of sufficient size, and sufficient excess treatment capacity in the sewage plant. It might be noted here that a land acquisition cost of $30,000 per acre would add $1,000 per acre drained to the cost of this type of treatment facility. And, a recent check in Philadelphia indicates that some river-front land is currently valued at upwards of $100,000 per acre. The costs of separation of sewers (Scheme 1) and of sub-surface impounding (Scheme 3) were not reduced to the 10-mgd base.

The cost of the Microstrainer and low-residence-time chlorination facility was developed from base costs. Figure 15 shows the cost per cfs of design capacity. This figure also illustrates an economy that should be realized as plant size is increased. As previously noted, this facility includes provision for bypassing excess flow equal to the design flow.

The Microstraining-chlorination scheme is, as shown on Table 6, the most economical on-site treatment scheme on the basis of capital cost. As will be seen in a later section, it is also one of the most economical on the basis of operating cost.

Annual Costs of Combined Storm Sewer Overflow Facilities

To arrive at uniform annual costs, some broad assumptions are made:

1. Where the overflow is to be treated at the overflow point, the elevation of the overflow is such that water will flow through a gravity-type plant and then to the receiving stream without repumping.

2. Rain occurs as 30 to 40 events per year producing overflow.

3. Rainfall volumes reaching a treatment facility total 90,000 cubic feet per year per acre (equivalent to 40 inches of rain at a runoff coefficient of 0.6).

4. Where a combined-sewer-overflow impounding basin is used, it is so located with respect to the sewage treatment plant, and is served by an existing interceptor of such size, that 50 feet of head is required for pumping from a surface basin and 200 feet of head for pumping from a sub-surface basin.

5. Annual capital charges are based upon amortizing, on a straight-line basis, the installed cost of the facility (less land) over 20 years, and upon interest charges at the annual rate of 5% of first cost. That is, the annual capital charge is the installed cost of the facility divided by 10.

6. Oxidant dosages of 5 ppm chlorine or 5 ppm ozone are used, except in Scheme 9, where 15 ppm of chlorine is used.

7. The flow-rate capacities of the various treatment steps are as cited in the previous section on Capital Costs.

8. Maintenance supplies, replacement parts, and maintenance labor, in addition to operator labor listed elsewhere, will amount to 1% of the capital cost per year.

The basis for the costs shown in Table 7 are:

	$ / acre-yr
Cost of pumping total flow to 50 feet head (@ 60% eff @ 1¢/kwh)	1.80

Cost of pumping total flow to 200 feet head (@ 60% eff @ 1¢/kwh)	7.20
Cost of pumping 3% waste flow to 50 feet (@ 60% eff @ 1¢/kwh)	.06
Cost of pumping 25% aeration flow to 60 psig (@ 60% eff @ 1¢/kwh)	1.20
Cost of 1 horse power continuous drive (@ 1¢/kwh)	8.25
Cost of 1 ppm chlorine (@ 42¢/# available Cl_2)	2.40
Cost of ozone, 1 ppm ($5.20/# from O_2 @ 19¢/#)	30.00
Cost of 1 ppm polymer (@ 50¢/#)	2.80
Cost of one visit (8-man hr @ $4.00/hr)	4.10

The power costs do not include demand changes which might be an additional 15% for infrequent demands. Power costs for ozone generation are included in oxidant cost.

The operating costs for the several schemes as shown in Table 7 are strongly influenced by the method of treating capital costs and maintenance costs. The costs of electric power, labor and chemicals are almost negligible, although high on a cents per 1,000 gallons basis, when spread over approximately 675,000 gallons per acre-year of combined sewer overflow.

The labor costs are based upon weekly or twice-weekly visits of operators, or in the case of the Microstrainer, a visit after each of the estimated 40 rain events per year.

Several of the treatment steps; e.g., dissolved air flotation, activated sludge, etc., normally require a startup period of at least 30 minutes. No impounding capacity has been provided prior to these steps, nor have power and other costs been included to operate these treatment

TABLE 7

ESTIMATED OPERATING COSTS OF PROPOSED
COMBINED SEWER OVERFLOW TREATMENT FACILITIES

Scheme No.	Description	Capital at 10% per year	Maintenance Supplies and Replacement Parts at 1% of Capital Cost	Power Cost	Labor	Oxidant	Other	Total Oper and Maint	Capital Plus O&M Total
1	Separate storm sewer	2,300	70*	-	-	-	-	70	2,370
2	Surface impoundment	650	65	2 pump	160	-	-	227	877
3	Sub-surface impoundment	2,500	250	8 pump	-	-	-	258	2,758
4	Primary clarifier - "Bio-Disc" secondary clarification	4,200	420	8 disc	208	12	-	648	4,848
5	Primary clarification - high rate aeration clarification	4,700	470	13 blower	416	12	-	911	5,611

*Lower figure used for sewer maintenance

TABLE 7 (continued)

ESTIMATED OPERATING COSTS OF PROPOSED
COMBINED SEWER OVERFLOW TREATMENT FACILITIES

Scheme No.	Description	Capital at 10% per year	Maintenance Supplies and Replacement Parts at 1% of Capital Cost	Cost	Labor	Oxidant	Other	Total Oper and Maint	Capital Plus O&M Total
6	Cyclone-dissolved air flotation	1,600	160	1 compressor 1 pump	208	12	-	382	1,982
7	Screen and dissolved air flotation	1,500	150	1 compressor 1 pump	208	12	Polymer 3	375	1,875
8	Primary clarification - powdered carbon and regeneration	1,550	155	8 miscl	416	12	Carbon 74	665	2,215
9	Microstraining-chlorination	1,050	105	8 drum	160	36	-	309	1,359

TABLE 7 (continued)

ESTIMATED OPERATING COSTS OF PROPOSED
COMBINED SEWER OVERFLOW TREATMENT FACILITIES

Scheme No.	Description	Capital at 10% per year	Maintenance Supplies and Replacement Parts at 1% of Capital Cost	Cost	Labor	Oxidant	Other	Total Oper and Maint	Capital Plus O&M Total
10	Microstraining-ozonation	1,980	198	8 drum	160	150	-	516	2,496

All values dollars per acre-year (based on a single 10 mgd, 7.8 acre installation).

steps continuously, since it is anticipated that these treatment steps would be adapted to intermittent service.

In contrast to all the other treatment schemes whose annual costs were developed from estimates of labor requirements, from calculated power and chemical requirements, etc., the Microstrainer-2 minute chlorination (at 15 ppm) scheme costs were developed from a detailed design and actual operating experience under storm conditions. In Schemes 1 through 8, the cost of a conventional chlorination chamber with a nominal 10 mgd capacity, operating on 30 mgd of storm water with a 5 ppm chlorine dose, is used.

These costs are, by the nature of the available data, quite crude. They are, however, considered sufficiently accurate to rank the several schemes according to their attractiveness in combined-sewer-overflow service.

It should be noted that these annual costs have been estimated for a single plant. Multiple installations in any given general locality would incur lower "per plant" labor and maintenance costs.

SECTION X

PROBLEMS ENCOUNTERED

Longer trough retention times were needed for extended operation periods. The 13,000-gph pump was too large for the lighter rainfalls and lower flows into the retaining trough. A second, smaller pump was added.

Drains became clogged, which caused solids buildups near pump inlets.

Direct sewer flow into the Microstrainer by gravity, with in-line bar screening, would eliminate the need for a surge facility and/or supply pumps. The bar screen can be manually or automatically operated.

The sewer overflow regulator at high sewer flows was found to be forced open to a larger-than-normal setting. This condition sometimes prevented small storms from flowing to the retention trough. Debris blocked the regulator at times and false startups would follow. Improved sewer overflow regulators are needed.

The air drying system for the Microstrainer controls on drum rate and differential head required frequent attention and maintenance. Electrical instrumentation can be substituted for air-operated controls.

The chlorination unit was not used due to operating problems. The use of gaseous chlorine is undesirable and presents problems in storage. Liquid sodium hypochlorite was used on bench samples at the test site. The sodium hypochlorite is easily stored and handled.

Operation of the ozone equipment was hampered by a refrigeration unit failure. The refrigeration unit is part of the air preparation system providing moisture-free air to the ozone generator. Injection nozzles must be sized and calibrated according to liquid flow rate, to insure a proper mixture of air-ozone and water.

The use of oxygen on a once-through basis, in place of the air, would eliminate the need for an air preparation system. The ozone generator would operate under pressure, with the water flow by gravity.

Composite samplers were employed to obtain samples of the raw and Microstrained water. This type of sampling is not so representative of variations within a storm. More information about a storm could be

obtained if samples were taken and stored individually. The low suction-lift capability of the samplers hindered their operation.

It can be seen that some of these problems are unique to an installation that is intended for investigative work. Still others would apply as well to operation of a full-scale plant of this type. For example: air-operated controls for the Microstrainer are standard and have good operating records for continuously-operated Microstrainers. Also, ozonators operated on air are widely and satisfactorily used in municipal water treatment applications.

SECTION XI

ACKNOWLEDGEMENTS

This work was carried out and the report prepared by G.E. Glover, Research Engineer, and P.M. Yatsuk, Associate Engineer, under the general direction of W.A. Keilbaugh, Manager of Research and Development.

The Cochrane Division of Crane Co. is greatly indebted to Mr. Allyn Richardson, Project Officer, FWQA, Boston, Mass., and Mr. Darwin Wright, Project Manager, FWQA, Storm and Combined Sewer Pollution Control Branch, Washington, D.C., for their assistance and cooperation in this program.

The cooperation of the City of Philadelphia Water Department, Mr. S. Baxter, Commissioner, their Water Pollution Control Division under Mr. C.F. Guarino, the Research and Development Group under Mr. J. V. Radzuil and the Analytical Group at the Northeast Laboratories under G. Carpenter, are gratefully acknowledged.

Plant design and its early operation were carried out by Messrs E.W.J. Diaper, Manager of Municipal Water and Waste Treatment and Mr.J.D. Reilly, both of the Cochrane Division, Crane Co.

This program is sponsored by the FWQA of the U.S. Department of the Interior under Contract No. 14-12-136.

STATEMENT OF INVENTION

The Cochrane Division, Crane Co., does hereby certify that to the best of its knowledge and belief, no inventions have resulted from performance under this contract.

SECTION XII

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Cochrane Division, Crane Co., Microstraining and Disinfection of Combined Sewer Overflows, FWQA Program Number 11023 EVO, June 1970.

ABSTRACT

Microstraining(C), using a Microstrainer screen of a nominal aperture of 23 microns, removed up to 98% of the suspended solids from a combined sewer overflow. The sewer, in a residential area of Philadelphia, has an average dwf of 1,000 gph. The maximum combined sewer flow during rainstorms in one year of operation was 304,000 gph (11.3 cfs).

Volatile suspended solids removals with the above screen have averaged 68% and 71% during different test periods.

Results indicated that there was a slightly better kill of coliform group bacteria with chlorine than with ozone in the Microstrainer effluents when both were used at an initial nominal concentration of 5 ppm, with 5 to 12 minutes detention time. However, chlorine was applied at slightly higher levels and with better control than ozone.

Preliminary estimates of the costs of treatment via Microstraining, using tentatively-established throughput rates, show that the capital costs per acre of drainage would be approximately $10,200 for Microstraining alone, $11,200 for Microstraining plus chlorination, and $19,800 for Microstraining plus ozonation.

Of eight other currently-proposed schemes, whose costs were estimated, only surface impoundment (where aesthetically acceptable and where low cost land is available) appears competitive.

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ACCESSION NO.

KEY WORDS:

MICROSTRAINING

COMBINED SEWER OVERFLOWS

SOLIDS REMOVAL

OZONATION

CHLORINATION

BOD REMOVAL

TREATMENT COSTS

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*Microstraining, *Combined sewer overflow, *Suspended solids removal

27 Abstract

Microstraining(c)*, using a Microstrainer screen of a nominal aperture of 23 microns, removed up to 98% of the suspended solids from a combined sewer overflow. The sewer, in a residential area of Philadelphia, has an average dwf of 1,000 gph. The maximum combined sewer flow during rainstorms in one year of operation was 304,000 gph (11.3 cfs).

Volatile suspended solids removals with the above screen have averaged 68% and 71% during different test periods.

Results indicated that there was a slightly better kill of coliform group bacteria with chlorine than with ozone in the Microstrainer effluents when both were used at an initial nominal concentration of 5 ppm, with 5 to 12 minutes detention time. However, chlorine was applied at slightly higher levels and with better control than ozone.

Preliminary estimates of the costs of treatment via Microstraining, using tentatively-established throughput rates, show that the capital costs per acre of drainage would be approximately $10,200 for Microstraining alone, $11,200 for Microstraining plus chlorination, and $19,800 for Microstraining plus ozonation.

Of eight other currently-proposed schemes, whose costs were estimated, only surface impoundment (where aesthetically acceptable and where low cost land is available) appears competitive.

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ACCESSION NO.

ABSTRACT

Microstraining(C), using a Microstrainer screen of a nominal aperture of 23 microns, removed up to 98% of the suspended solids from a combined sewer overflow. The sewer, in a residential area of Philadelphia, has an average dwf of 1,000 gph. The maximum combined sewer flow during rainstorms in one year of operation was 304,000 gph (11.3 cfs).

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Results indicated that there was a slightly better kill of coliform group bacteria with chlorine than with ozone in the Microstrainer effluents when both were used at an initial nominal concentration of 5 ppm, with 5 to 12 minutes detention time. However, chlorine was applied at slightly higher levels and with better control than ozone.

Preliminary estimates of the costs of treatment via Microstraining, using tentatively-established throughput rates, show that the capital costs per acre of drainage would be approximately $10,200 for Microstraining alone, $11,200 for Microstraining plus chlorination, and $19,800 for Microstraining plus ozonation.

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KEY WORDS:

MICROSTRAINING

COMBINED SEWER OVERFLOWS

SOLIDS REMOVAL

OZONATION

CHLORINATION

BOD REMOVAL

TREATMENT COSTS

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Volatile suspended solids removals with the above screen have averaged 68% and 71% during different test periods.

Results indicated that there was a slightly better kill of coliform group bacteria with chlorine than with ozone in the Microstrainer effluents when both were used at an initial nominal concentration of 5 ppm, with 5 to 12 minutes detention time. However, chlorine was applied at slightly higher levels and with better control than ozone.

Preliminary estimates of the costs of treatment via Microstraining, using tentatively-established throughput rates, show that the capital costs per acre of drainage would be approximately $10,200 for Microstraining alone, $11,200 for Microstraining plus chlorination, and $19,800 for Microstraining plus ozonation.

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Preliminary estimates of the costs of treatment via Microstraining, using tentatively-established throughput rates, show that the capital costs per acre of drainage would be approximately $10,200 for Microstraining alone, $11,200 for Microstraining plus chlorination, and $19,800 for Microstraining plus ozonation.

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